AUTOMATIC ELECTRIC

TECHNICAL JOURNAL

THE NEW
SPEAKERPHONE—EXECUTIVE MODEL

JULY, 1961 VOL. 7, NO. 7

GENERAL TELEPHONE SYSTEM

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The Automatic Electric Technical Journal is published by
AUTOMATIC ELECTRIC LABORATORIES, INC., a subsidiary
of Automatic Electric Company, Northlake, Illinois, U.S.A.,

and the affiliated laboratories of

Leich Electric Company, Genoa, Illinois, U.S.A.
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AUTOMATIC ELECTRIC TECHNICAL JOURNAL

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En este nuevo teléfono, la conmutación parcial de la ganancia posibilita altos niveles de señalización sin "canto" ni mutilación. El empleo de la "base flotante" mejora su apariencia y duplica el espacio para la colocación de sus partes.

LE NOUVEAU TELEPHONE A HAUT PARLEUR — MODELE "EXECUTIVE"

Le controle automatique du gain de ce nouvel appareil permet une haute amplification sans amorcage ni distorsion. Le nouveau concept de base "flottante" permet de doubler l'espace réservé aux organes.

IL NUOVO TELEFONO CON ALTOPARLANTE — "EXECUTIVE MODEL"

Un sistema di controllo parziale del guadagno permette, in questo nuovo telefono, segnali ad alto livello con l'eliminazione dell'effetto Larsen e dell'innesco. Un nuovo sistema di montaggio a "base fottante" raddoppia lo spazio disponibile per i componenti.

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INTERCONNECTION ENTRE CENTRAUX STROWGER ET CENTRAUX ROTARY

Automatic Electric a étudié un systeme d'interconnection permettant l'extension d'un central rotary 7A2 et sa liaison au réseau automatique interurbain national, sans la nécessité de modifier l'appareillage existant.

INTERCONNESSIONE FRA EQUIPAGGIAMENTI STROWGER E ROTARY

Per consentire l'ampliamento di una centrale Rotary 7A2 ed il relativo allacciamento alla rete di teleselezione nazionale, la Automatic Electric ha sviluppato equipaggiamenti di intrconnessione che non richiedono alcuna modifica alle apparecchiature della centrale esistente.

"HIGH-VOLTAGE" LOADING COILS . . . . . **Page 245**

These coils will withstand a 10 kilovolt pulse between windings, and 20 kilovolts to ground. Designed for installation in re-enterable splice cases; also in lead cases for strand or pole mounting.

BOBINAS DE CARGA DE "ALTA TENSION"

Estas bobinas pueden resistir impulsos de 10 kilovoltios entre devanados y 20 kilovoltios a tierra. Proyectadas para instalarse en cajas de empalme accesible, así como en cajas de plomo para colocarse en cable mensajero o en postes.

WALTER AXELSEN
Editor

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BOBINES DE CHARGE "HAUTE TENSION"

Ces bobines peuvent supporter une impulsion de 10 kilovolts entre enroulements et de 20 kilovolts a la terre. Etudiés pour l'installation dans des boites de raccordement; offertes aussi en boites de plomb pour installations sur poteau ou suspendues.

BOBINE DI PUPINIZZAZIONE AD "ALTA TENSIONE"

Queste bobine possono sopportare un impulso di 10 kV tra gli avvolgimenti, e 20 kV verso terra. Sono state progettate per installazione sia in cassette di raccordo apribili che in cassette di piombo per montaggio su palo.

AN EXPERIMENTAL SATT TABULATOR USING FERRITE CORES . . . . . **Page 249**

The requirements, circuits, and design philosophy of a SATT Tabulator using ferrite cores in lieu of codel relays, which was developed in an investigation of data-storage techniques applicable to telephony.

TABULADOR EXPERIMENTAL SATT QUE EMPLEA NUCLEOS DE FERRITA

Requisitos, circuitos y principios de diseño de un Tabulador SATT que emplea núcleos de ferrita en vez de relevadores codel, producto de la investigación de métodos de almacenamiento de información digital aplicables en telefonía.

TABULATEUR EXPERIMENTAL SATT UTILISANT DES NOYAUX DE FERRITE

Conceptions, circuits et caractéristiques d'un tabulateur SATT utilisant des noyaux de ferrite au lieu de relais. Ce tabulateur fut étudié au cours de recherches sur les techniques de mémoire applicables a la téléphonie.

UN TABULATORE SPERIMENTALE SATT CON NUCLEI DI FERRITE

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THE TYPE TRC-2 TRANSISTOR RINGING CONVERTER . . . . . **Page 253**

This d-c to a-c converter operates from 48-volt exchange battery and provides five frequencies of ringing current in any of the three standard series. Each frequency is provided by a separate plug-in unit.

CONVERTIDOR TRANSISTORIZADO DE CORRIENTE DE TIMBRE TIPO TRC-2

Este convertidor de c-c a c-a es alimentado por la bateria central de 48 V. y proporciona cinco frecuencias de corriente de timbre en cualquiera de las tres series convencionales. Cada frecuencia es suministrada por una unidad enchufable separada.

LE CONVERTISSEUR DE COURANT D'APPEL TRC-2, TRANSISTORIZE

Ce convertisseur de courant continu en alternatif est alimenté par la batterie de 48 volts du central et offre cinq fréquences de courant d'appel dans n'importe quelles des trois séries standard. Chaque fréquence est produite par un organe individuel a fiches.

IL CONVERTITORE DI CHIAMATA TRANSISTORIZZATO TRC-2

Questo convertitore da corrente continua a corrente alternata viene alimentato dalla batteria di centrale a 48V e genera cinque frequenze di corrente di chiamata in qualsivoglia delle tre serie standard. Ogni frequenza viene prodotta da un' unita singola ad innesto.

TEST AND INSTALLER'S SET FOR AT-6 NEGATIVE-IMPEDANCE REPEATERS . . . . . **Page 258**

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APARATO DE PRUEBA Y DE INSTALADOR PARA REPETIDORES AT-6 DE IMPEDANCIA NEGATIVA

Todo el equipo que normalmente se necesita para la instalación, alineamiento y prueba del repetidor serie-paralelo AT-6 está incorporado en esta pequeña unidad portátil que puede emplearse también para otras pruebas distintas.

APPAREIL POUR L'ESSAI ET L'INSTALLATION DE L'AMPLIFICATEUR A IMPEDANCE NEGATIVE AT-6

Tout l'équipement normalement nécessaire pour l'installation, l'alignement et l'essai de l'amplificateur a impédance négative série-parallele AT-6, est contenu dans cet appareil portatif, de faible encombrement qui peut également servir a prendre d'autres mesures.

APPARECCHIO DI PROVA ED INSTALLAZIONE DEL RIPETITORE AD IMPEDANZA NEGATIVA AT-6

Questo apparecchio, compatto e portatile, contiene tutte gli strumenti necessari per l'installazione, messa a punto e prova del ripetitore combinato serie-parallelo AT-6. Inoltre esso puo servire per varie altre misure.

THE NEW SPEAKERPHONE— EXECUTIVE MODEL

By R. T. Cleary and T. G. Cannon
Automatic Electric Laboratories, Inc.

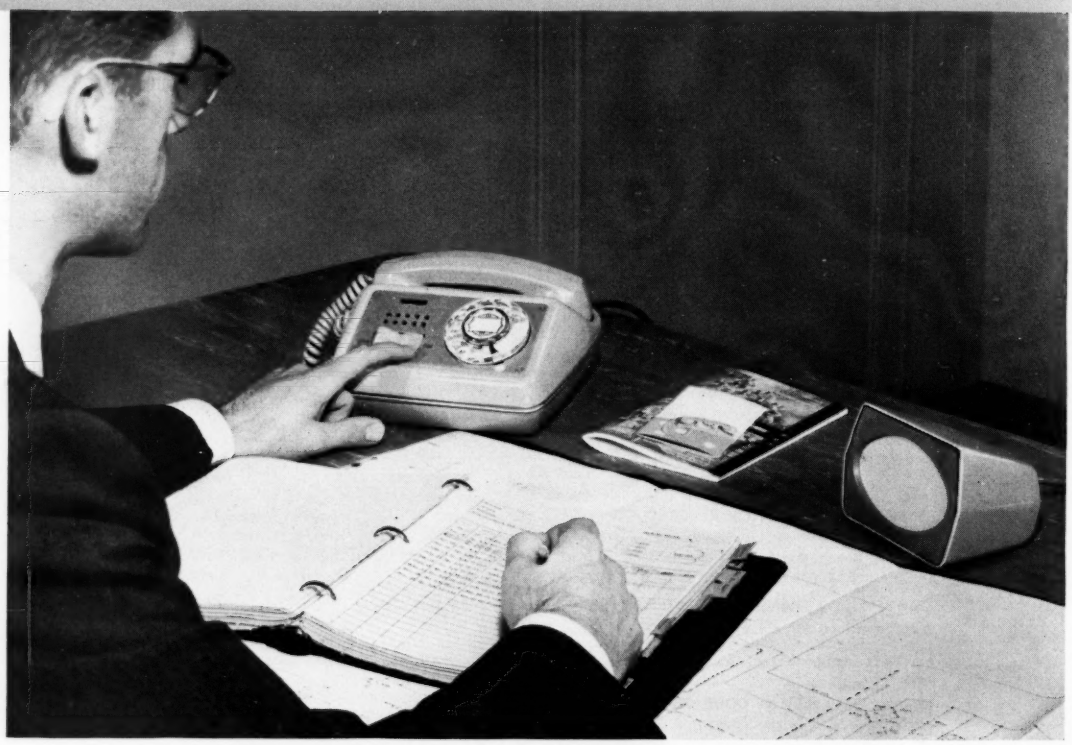


Figure 1. This new Loudspeaking Telephone, with its unique housing and simple controls, provides "no hands" operation for an individual or a group of people.

Loudspeaking telephones offer two obvious advantages over other instruments: (1) "No hands" operation, and (2) "Group conversation" (i.e., a number of persons gathered in an office, or an entire family around the telephone, can all hear and be heard at the same time). With these inherent advantages, it was felt that the market for such a telephone would be greatly increased if by means of voice-switching techniques it could be made acoustically satisfactory, and if by use of "human-factors" engineering it were made convenient to use, and given a distinctive appearance that would visually convey the idea of a loudspeaking telephone instrument.

Probably the greatest problem was to make a loudspeaking telephone which would give transmission at a normal handset level to the line, and yet not have loudspeaker-microphone acoustic feedback ("singing") or echo; with the decision to use gain-switching in the new telephone, we were on the way to solving this problem.

But there were other problems. Simple gain-switching usually results in the "clipping" of first syllables, and also makes it impossible for

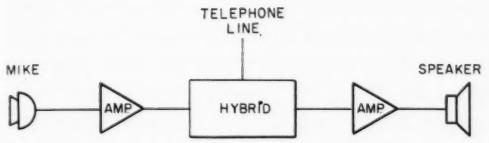


Figure 2. The basic circuit of every loudspeaking telephone includes amplifiers and a hybrid balancing network.

a listener to interrupt the speaker; under these handicaps, conversation is somewhat unnatural. Some modification of usual gain-switching techniques was therefore indicated. At the same time, although a loudspeaking telephone is inherently a more complex device than an ordinary telephone, it was necessary to make the new instrument as simple as possible to install and maintain. Automatic Electric's Speakerphone—Executive Model (see Figure 1) was designed with these difficulties in mind—and we feel that they have been almost entirely overcome.

Besides this, the new design departs from existing designs of telephone housings, not only to make a distinctive appearance but to actually *look* like a loudspeaking telephone!

Causes of Feedback and Echo Problems

A loudspeaking telephone in its most basic form consists of a microphone (or "mike"), a loudspeaker, and their associated amplifiers, connected to the telephone line via a hybrid balancing network (see Figure 2).

The hybrid network is a bridge circuit used to couple the microphone and loudspeaker amplifiers to the line while minimizing the electrical coupling between these amplifiers.

The ideal hybrid network should be exactly balanced against the impedance of the line, but since this varies with the characteristics of the particular line and its distant terminating impedance, some coupling always exists.

Loudspeaker and microphone placement, as well as room acoustics, also have a considerable effect on operation. If there is excessive loudspeaker-microphone coupling and an unbalanced hybrid network, the electro-acoustic feedback loop will cause singing. Even with a balanced hybrid, with the gain and acoustic coupling below the singing point, the distant party may still hear a delayed echo of his voice, because of acoustic coupling of loudspeaker and microphone. This is bothersome and hampers normal conversation.

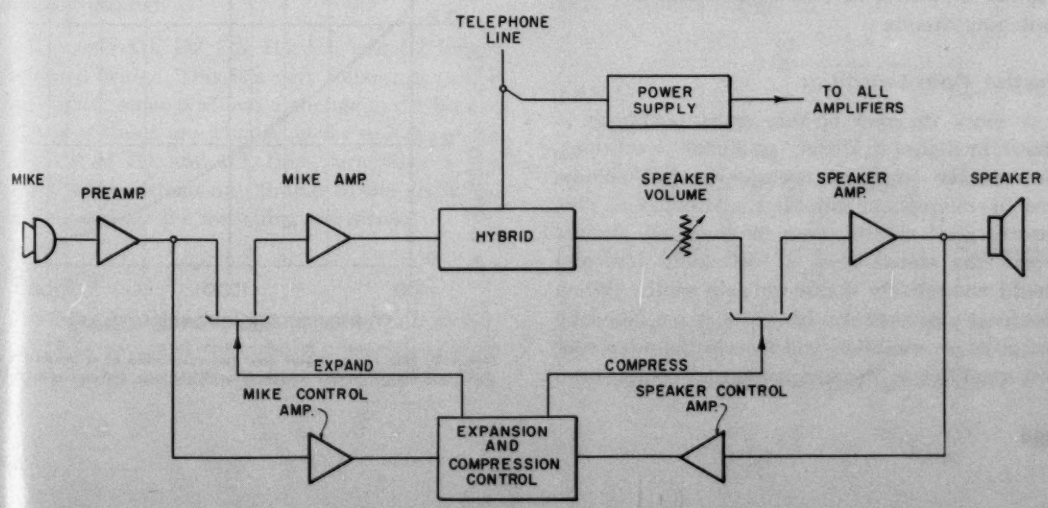
Singing and echo problems can be decreased by a reduction in amplifier gain, but of course this is not a satisfactory solution. Telephone users expect to hear at about a normal volume, and we set out to meet this requirement.

Voice-Switching Techniques

There are several criteria for a good voice-switching circuit:

1. It must have a fast "attack time" (the in-

Figure 3. The Speakerphone—Executive Model, has supplemental amplifiers and controls, to provide ample transmission volume without "singing".



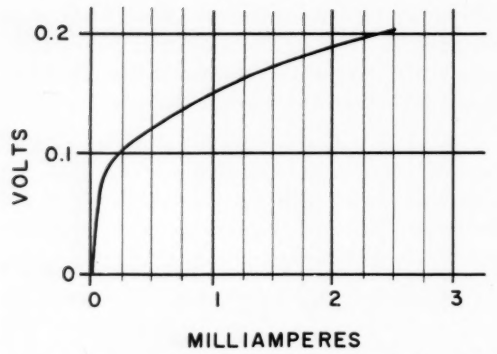


Figure 4. This curve shows that the current through a diode varies with the voltage drop across it.

terval beginning when a voice signal enters the mike or speaker channel and ending when that channel is operating at full gain). If the attack time is too slow, first syllables will be clipped.

2. It must have a slow enough "decay time" (beginning when the speech signal ends and ending when the channel is reasonably attenuated) so that switching does not occur between syllables, and so that stressed and unstressed syllables in speech are amplified at the same rates. On the other hand, if the decay time is too long, rapid back-and-forth conversation will not be possible, since the channels will remain active too long.

3. Switching should be smooth, with no click or other disturbing noises.

4. To make interruptions possible, the circuit should be arranged to prevent exclusive holding of a channel.

The above requirements were achieved with a great degree of success in the present design, by the use of diodes as nonlinear elements in the switching circuits.

Partial Gain-Switching

A block diagram of this novel telephone is shown in Figure 3. Under "no signal" conditions, the speaker amplifier operates at full volume and the microphone amplifier is attenuated. This insures good results, even on long toll circuits where the signal level is extremely low and would not reliably operate a gain switch. When the local party speaks, his voice is amplified by the mike preamplifier, and fed via the mike control amplifier to the expansion and compression control. The signal causes the microphone amplifier to be expanded (gain increased 20 db) while the speaker amplifier is compressed (gain reduced 20 db). Total loop gain can thus be increased 20 db over that of a non-gain-switched circuit, without increased singing and echo.

When the distant party speaks, his speech is amplified by the speaker amplifier and reproduced by the loudspeaker. Part of the signal is sent to the expansion and compression control via the speaker control amplifier. (Although the speaker amplifier is normally expanded, it is still necessary that a speaker control circuit be present. This control acts as a protective device, so that when the speaker channel is in use, noise and signal which may enter the microphone as speech will not cause speaker attenuation).

Diode Control Circuits

The forward characteristic of a typical germanium diode is shown in Figure 4. It is readily apparent that the resistance of the diode decreases as the d-c biasing voltage across it (in the forward direction) increases. If an incremental a-c voltage is superimposed on the d-c biasing voltage, the dynamic resistance (resistance to the a-c voltage) is increased as the d-c voltage decreases—(see Figure 5). Thus a diode can be used in an audio circuit to control the gain of that circuit, by using a d-c biasing voltage to change the dynamic resistance of the diode.

Compression

A practical circuit for attenuating a signal by increasing the d-c biasing voltage is shown in Figure 6. Figure 6A shows a T-network with a

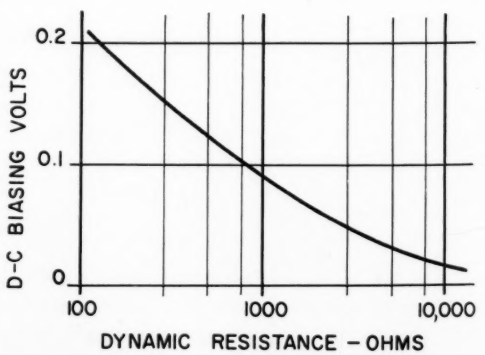
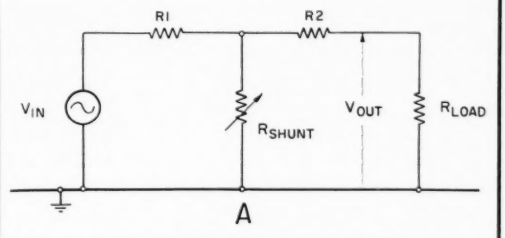
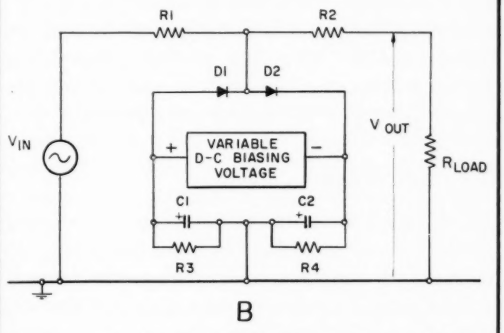


Figure 5. This curve shows that the resistance of a diode to a small a-c signal varies inversely with the d-c voltage across it.



A T-network with variable shunt resistance to compress (reduce the level of) an audio circuit.



The same network, with variable shunt replaced by diodes.

Figure 6. Principle of the audio compression circuit.

variable shunt element, R shunt. We now replace this shunt by diodes, D1 and D2 (Figure 6B). It must be remembered at this point that the a-c voltage is small (100 mv or less for germanium diodes) and therefore causes movement over only a small part of the dynamic resistance curve, resulting in extremely small nonlinear distortion. An increase in the d-c biasing voltage causes forward biasing of the diodes, decreasing their dynamic resistance and causing attenuation of the audio signal. Capacitors C1 and C2 bypass the audio to ground.

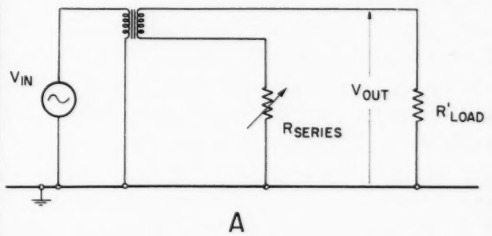
Elements D1, D2, R3, R4, C1, and C2 form a balanced bridge. This is a very important part of the circuit, since it allows a change in d-c biasing voltage without any change in d-c voltage at the junction of R1 and R2, thus permitting a fast attack time without any thump in the audio circuit caused by d-c switching transients.

Expansion

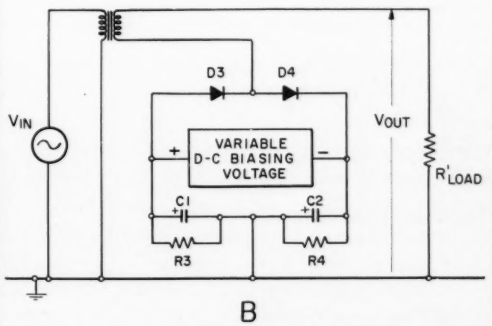
In a loudspeaking telephone using gain-switching, it is required that the d-c control voltage which compresses one channel expand the other. The method used is shown in Figue 7. Figure 7A shows how the audio output level is increased (expanded) when R series is decreased in resistance. Figure 7B shows how this is accomplished with diodes. Operation is identical with that of the compression circuit, except that decreasing the resistance of the diodes expands the signal rather than compressing it.

A signal in the speaker-control amplifier causes a d-c voltage which is subtracted from the mike-control d-c voltage. This prevents stray noises and speaker echo in the microphone channel from operating the expansion-compression circuit when the speaker channel is in use.

There are several interesting points to be noted about the combination of the expansion and compression circuits. This combination requires two diodes in the compression circuit, and four diodes in series in the expansion circuit (although only two are shown in the simplified diagram—Figure 7B). If two diodes were used in each circuit, total loop gain (microphone channel gain times speaker channel gain) would be increased during switching, causing feedback problems. With the



Network with variable shunt resistance to increase (expand) the output of an audio circuit.



The same network, with variable shunt replaced by diodes.

Figure 7. Principle of the audio expansion circuit.

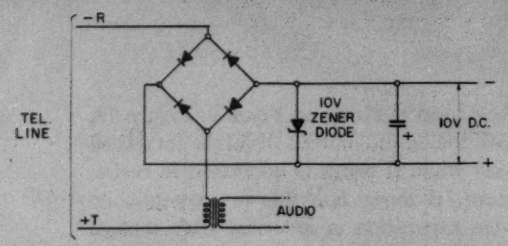


Figure 8. The telephone line supplies power as well as audio signal for the loudspeaking circuit. The diode bridge assures proper polarity, irrespective of line polarity.

present arrangement, more d-c voltage is required in the expansion circuit to produce the same dynamic resistance. This gives a very desired characteristic, and loop gain remains almost constant throughout the entire switching range.

Resistors shunted by 2 MF capacitors are used in series with the diodes, to "soften their knee". Their use is very important to smooth operation. The resistors limit diode current, and the capacitors are for audio bypass. Without these elements, operation is choppy, and stressed syllables are further stressed while unstressed syllables are made even softer.

Power Supply

Power for operation of the Type 880 telephone is derived from the telephone line, using an arrangement (see Figure 8) which is generally applicable to electronic telephone circuits. The diode bridge is used so that the output voltage will be of proper polarity even under reverse-battery conditions. A 10-volt power Zener diode holds the voltage within 3 per cent, from zero loop to 1000-ohm loop. Under certain conditions, such as greater than 1000-ohm loop, or certain high-resistance battery feed switchboards. (Western Electric 555, Leich L55), an external power supply, operated from commercial power, is used.

Flashing Lamp "On" Signal

Since the handset of a loudspeaking telephone remains in its cradle even while the telephone is in use, it would be very easy to leave the unit on after use, if no other indication were provided. Mechanical indicators have never been satisfactory, and usually not enough power is available from the telephone line to operate an incandescent lamp. A flashing neon lamp is therefore used in the new Speakerphone. The 10-volt supply powers a 50 KC transistor oscillator (3 ma current drain), the secondary of which provides 150 volts of 50 KC. This is rectified and filtered, and feeds a neon R-C relaxation oscillator that flashes the neon indicator (encased in the ON-OFF button) at a rate of 20 flashes per minute.

Electronic Ringer

The Type 880 Loudspeaking Telephone responds to ringing current of any standard frequency (16-66 cps), on single-party or two-party selective ringing lines. The ringing current is rectified and filtered, and the resulting d-c voltage is used to power a two-frequency oscillator, operating at 2,000 cps and quenched at 12 cps. The oscillator signal is amplified by the ringer output transistor, and is fed to the same loudspeaker used for loudspeaking operation.

Housing the "Speakerphone"

The elements of the "Speakerphone" which are most intimately related to the user are the dial, the ON-OFF switch, and the loudspeaker volume control; the handset is less closely associated with the user since, in a telephone of this type, it is used comparatively seldom. In

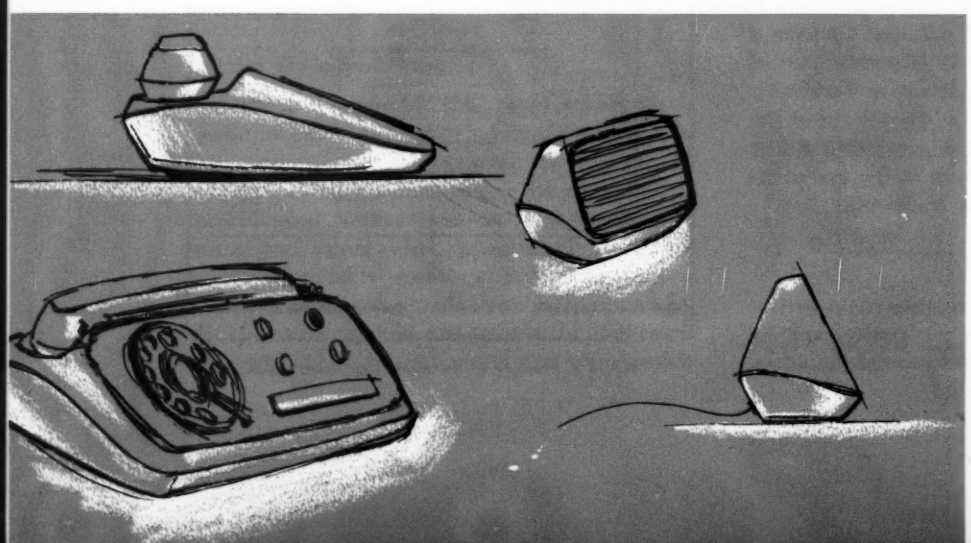


Figure 9. Designer's original sketch for the new Speakerphone.

arranging these elements, the dial and the loudspeaker controls were placed next to each other on an inclined panel, so they are equi-distant from the user and easily seen (see cover picture). The handset was placed back of this panel, making it of secondary importance to the loudspeaking feature, yet easy to reach with either hand. The long axis of the base was thus placed parallel to the handset, so the depth of the telephone could be reduced, while its length would be only that of the handset.

To decrease the time needed to get the new telephone into production, the housing was designed so it could be either injection-molded or vacuum-formed. The latter is a process which forms sheet plastic materials to a mold by the application of heat and air suction. Parts to be produced by vacuum-forming must have shallow draws and liberal draft, to prevent excessive thinning of the material. Angular forms which are difficult to draw were therefore avoided in favor of those with curves of larger radius, and since, with vacuum-forming, there is no opportunity to introduce reinforcing ribs, the continuously curved surfaces were designed to provide necessary rigidity in the housing.

The original sketch from which the Speakerphone was developed is shown in Figure 9. Note that the housing was split into upper and lower sections, so as to meet the requirement for shallow draws, and still provide enough vertical space for the components. This concept became the basis for the unique design of the Speakerphone.

When the Speakerphone is assembled, the shallow upper and lower housings cover the components, which are mounted to an aluminum center plate (see Figure 10), made by riveting two identical shallow-drawn "pans" back to back. The flanges on the edge of this center plate are then used for aligning the housings and covering their trimmed edges.

The lower housing is held in place by three screws which go into brackets mounted to the centerplate. These same brackets act as legs when the housings are removed for maintenance.

The upper housing is secured by the screws that fasten the brushed aluminum faceplate to the control mounting plate.

Particular attention was given to the type and arrangement of controls used. A large rocker switch was chosen as the ON-OFF switch, because it would be easy to operate and its function would be obvious even to a person unfamiliar with the telephone. The flashing lamp that is used to indicate a seized line was mounted in the rocker switch so their close relationship would be apparent, and the rocker switch was mounted at the bottom of the panel so it is closer to the user than the other controls. Above the rocker switch, a group of small holes in the faceplate indicate the location of the microphone. The speaker volume-control wheel, mounted with its edge pro-

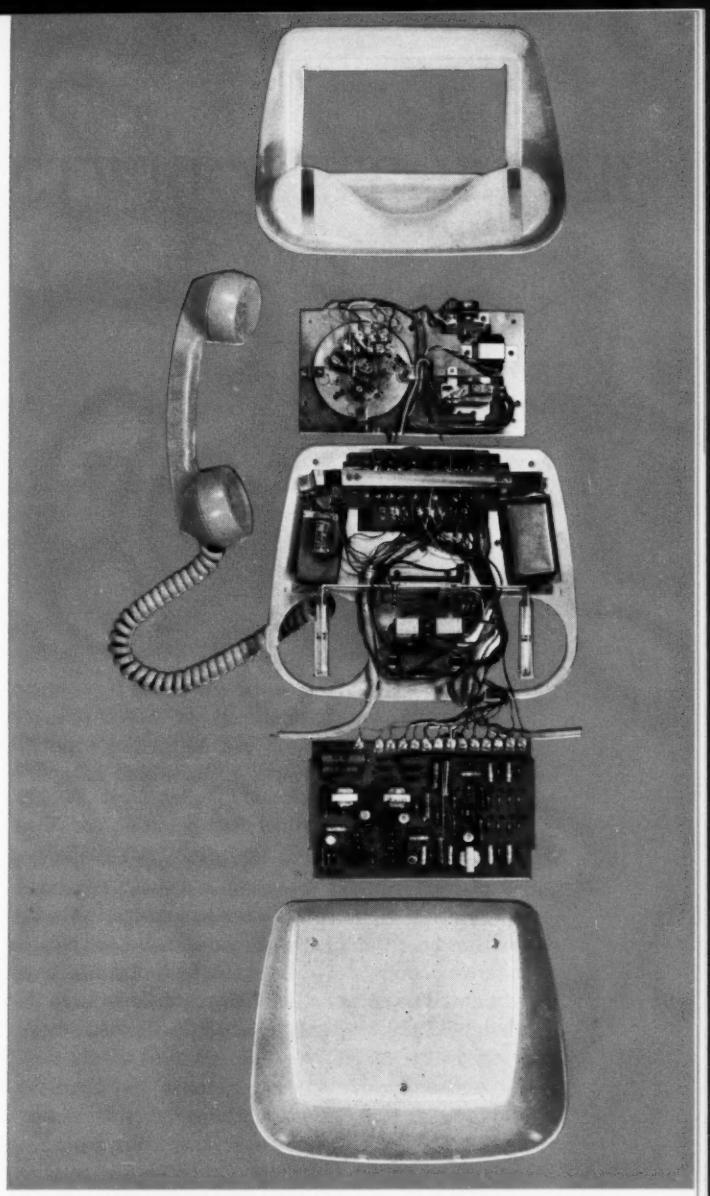


Figure 10. "Exploded" view of the Speakerphone. Working parts are mounted on the plate in the center, and on the faceplate and the printed wiring board which are connected to it. The two parts of the housing are shown at top and bottom.

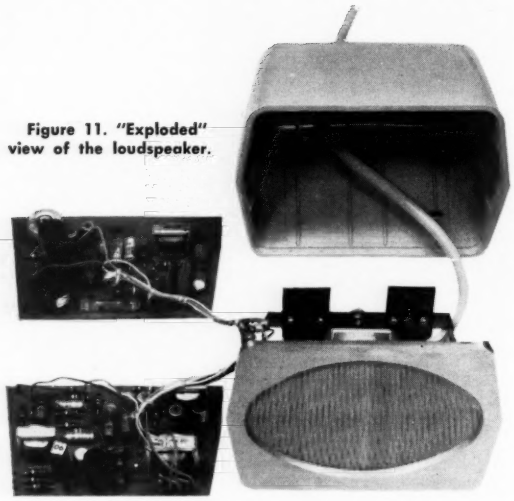


Figure 11. "Exploded" view of the loudspeaker.

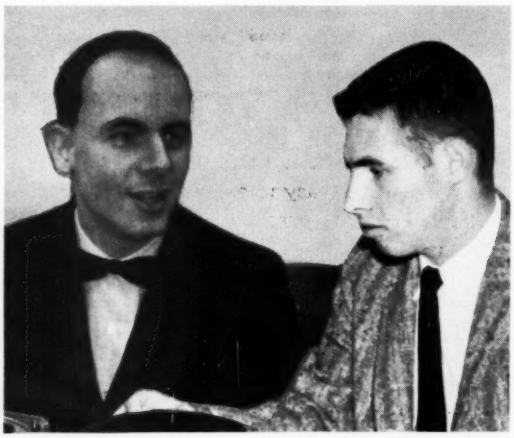
jecting through the faceplate, is above these holes, far enough away from the rocker switch to avoid being accidently moved, yet no further from the user than the uppermost finger-wheel hole.

Speaker Housing

The housing for the separate speaker holds a 3″ by 5″ speaker, the speaker-amplifier printed-wiring board, and the electronic-ringer printed-wiring board. With the shape of the speaker as a starting point, the printed-wiring boards were mounted on either side of the magnet to keep the height of the assembly at a minimum (see Figure 11). The tapering of the sides and top toward the rear gives the illusion of shallowness when viewed from the front, by eliminating any reference points which the eye might use to judge depth. A relationship to the main unit is created by the slight break about the middle of the speaker and by the use of a brushed aluminum faceplate. This diecast aluminum faceplate has studs in back, for mounting the speaker and holding the front edges of the printed-wiring boards. The rear edges of the boards are held by a clip that is mounted to the rear of the faceplate; a single screw, which goes through the back of the housing into this clip, draws the faceplate tightly into the housing.

Conclusion

Automatic Electric's Type 880 telephone, the "Executive" Speakerphone, was designed to overcome the difficulty experienced with other loudspeaking telephones, which sometimes sing because of feedback from the loudspeaker into the microphone. Partial gain switching obviates this problem, since with this new method the loudspeaker and the microphone are never "alive" at the same time—yet there is no "clipping" of syllabels, and the listener may interrupt the speaker at any time, as in normal conversation. All necessary controls are conveniently placed and clearly marked, and the design of the housing is so distinctive that it may well become a prototype of other telephones of the future!



Robert T. Cleary joined Automatic Electric Laboratories in 1960, after receiving a B.S. in E.E. from Illinois Institute of Technology. Since 1955, however, he had participated in the Co-operative Engineering program. Now in the Electronics Application Group of the Laboratories' Products Design Department, he has aided in the design of transistor loudspeaking telephones. He has four patents applied for in his own name, and another as co-inventor. At IIT he was student president of Rho Epsilon, honorary electronics fraternity.

Thomas G. Cannon received a B.S. in Industrial Design from I.I.T. Institute of Design in 1959. During summer vacations he had worked for the Laboratories' Product Design Department, and joined the Electromechanical Design Group of this Department, on an advanced telephone instrument development assignment. After his graduation, he developed the appearance designs of an electronic telephone exchange and of the Speakerphone-Executive Model. Now a member of the U.S. Army's First Support Group, he is stationed in New York.

NTERCONNECTION BETWEEN STROWGER AND ROTARY EQUIPMENT

By M. J. Finn & L. D. Sanson
General Telephone Company of Kentucky
Lexington, Kentucky

In the early '50's, Lexington was faced with the problem of concentrated growth in peripheral areas; service requirements were exceeding the regular facilities of the Main Office—a Rotary 7A2 type equipped with 18,000 lines and 28,800 terminals, located in the center of the city. Since it was felt that step-by-step equipment was most easily adaptable to existing requirements, and to the probable needs for future growth, it was decided to utilize Strowger Automatic equipment in a new central office, located in the southern part of the city, where the greatest growth had occurred and was expected to continue. Plans were also made for a future additional office in the eastern part of the city.

Five-digit numbers are now used throughout this area, but 7-digit numbers will ultimately be used, to meet the requirements of the nation-wide numbering plan. Conversion of the step-by-step offices to seven-digit numbers will be simple, as the selectors are designed for digit-absorption; the same problem will be more difficult and costly in the Rotary equipment, however, because all registers will have to be converted.

Engineers of Automatic Electric Laboratories and General Telephone Company of Kentucky were thus jointly involved in developing a method of interconnection between Strowger Automatic equipment and the 7A2 Rotary type automatic equipment. These plans of interconnection were concerned with the installation of new Strowger offices (#6 and #7), the addition of Strowger interworking equipment for service between the two types of systems, and the addition of Strowger intertoll dial equipment, to enable distant operators to extend calls into Lexington by dialing (this feature was not part of the problem of interconnection, but since such service was not provided by the Rotary equipment, it was decided to incorporate it at this time).

Elements of the Problem

In developing the interworking equipment, it was necessary to recognize that Strowger and Rotary systems differ fundamentally in several respects. Strowger is, of course, a decimal system, based on groups of 100 lines and an office capacity of 10,000 numbers; the switches are self-driven, and normally are controlled directly by the subscribers' dial pulses. The Rotary system is non-decimal; the basic group consists of 200 lines, and a complete unit may serve up to 20,000 terminals. The motor-driven Rotary switches do not respond directly to the subscribers' dials, but are controlled by a "register".

The register is a group of relays whose function is to receive and interpret the impulses dialed into the system by the calling subscriber; it then controls the movement and selection of all the remaining switches in the train necessary to complete that particular connection. The register knows from the digits dialed what levels are required. In order to control the selection, it passes this information on to an out-stepping counting train and then closes the metallic loop to start the switching operation, which sends one revertive pulse per step, operating one relay per pulse until the marker wire in the counting train is reached. When the register is thus satisfied that the switch has completed the proper number of steps, it sends a "stop" signal, to stop the Rotary switch at that point.

The fundamentally different methods of pulse control used in Strowger and Rotary operation necessitate the use of translating equipment (see Figures 1 and 2) for routing calls between the two systems. This equipment comprises (see Figure 3) Converters and outgoing trunk relay groups for calls from Rotary to Strowger, and Controllers and incoming selectors for calls from Strowger to Rotary. (In some cases, registers supplied in the Rotary system are designed to

interwork directly with step-by-step equipment, but this was not the case at Lexington, as such a requirement had not been foreseen. By providing Converters we obviated the necessity for conversion of the existing registers—which would not only have been costly but would have interfered with normal exchange service).

Since the main interworking equipment was similar in function to the Rotary and since, in the future, it would interwork with more than one remote office, it was decided to centralize all the interworking equipment in the Main office. Another major advantage in having the interworking equipment located in the same building as the toll boards would be the simplification of future inter-toll (long-distance) dialing equipment, because such inter-toll selectors could be step-by-step type. Furthermore, the concentration of all these special units in the Main office made it possible to operate the new offices on an unattended basis during the night and on weekends.

Other problems to be resolved initially were the opening of a level of the Rotary 1st group selectors to route traffic to the new office, and the allocation of the new office code. As a result of the inherent features of the existing registers, the new office code and the 1st selector level do not need to bear any relation to each other and may be chosen arbitrarily; digit "7" was selected for the initial Strowger Automatic office.

To release level 5 of the Rotary 1st selectors for the routing of traffic to the new offices, it was decided to change the numbers of 2000 subscribers in the 34,000-35,999 series. Those subscribers in this series who would continue to be served by the Rotary office were assigned to the 54,000-55,999 group, which would use level 3 of the 1st selectors jointly with the 40/50,000 numbers, through intermediate 3rd group selectors. The number change from 34/35,999 to 54/55,999 was readily made in the register in the Rotary equipment; the additional traffic necessitated the addition of Rotary 3rd group selectors. Subscribers who would be served through the step-by-step office were given numbers in the 74/75,999 series.

An interesting problem came up in connection with this number change. Although the group of 2000 numbers in the new step-by-step office was not to be cut over until December, it was desired to list them in the directory being issued in May. This was accomplished by strapping the

Figure 1. Converters on this rack provide revertive impulses to the registers in the Rotary equipment, and send forward to the Strowger equipment decimal pulses corresponding to those sent by a dial.

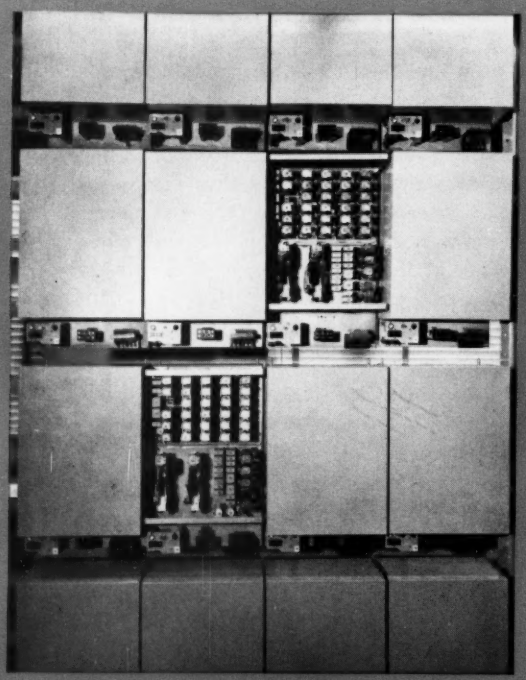
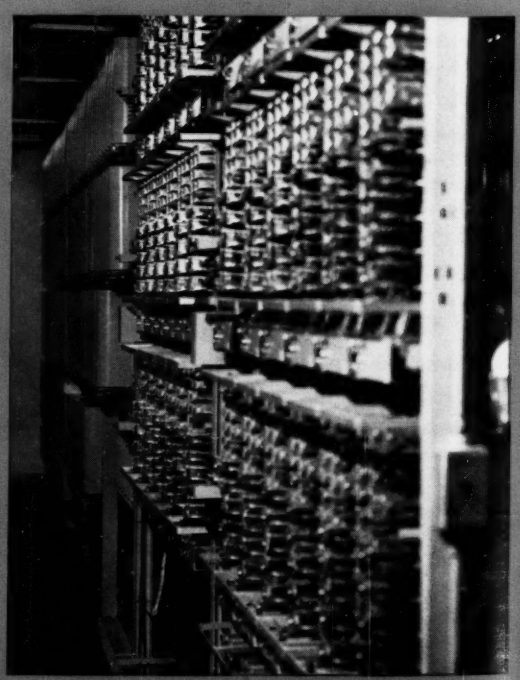


Figure 2. Controllers on this rack receive the last three digits dialed through the Strowger equipment, store them, and translate them into the Rotary code. Associated incoming selectors are shown in background.



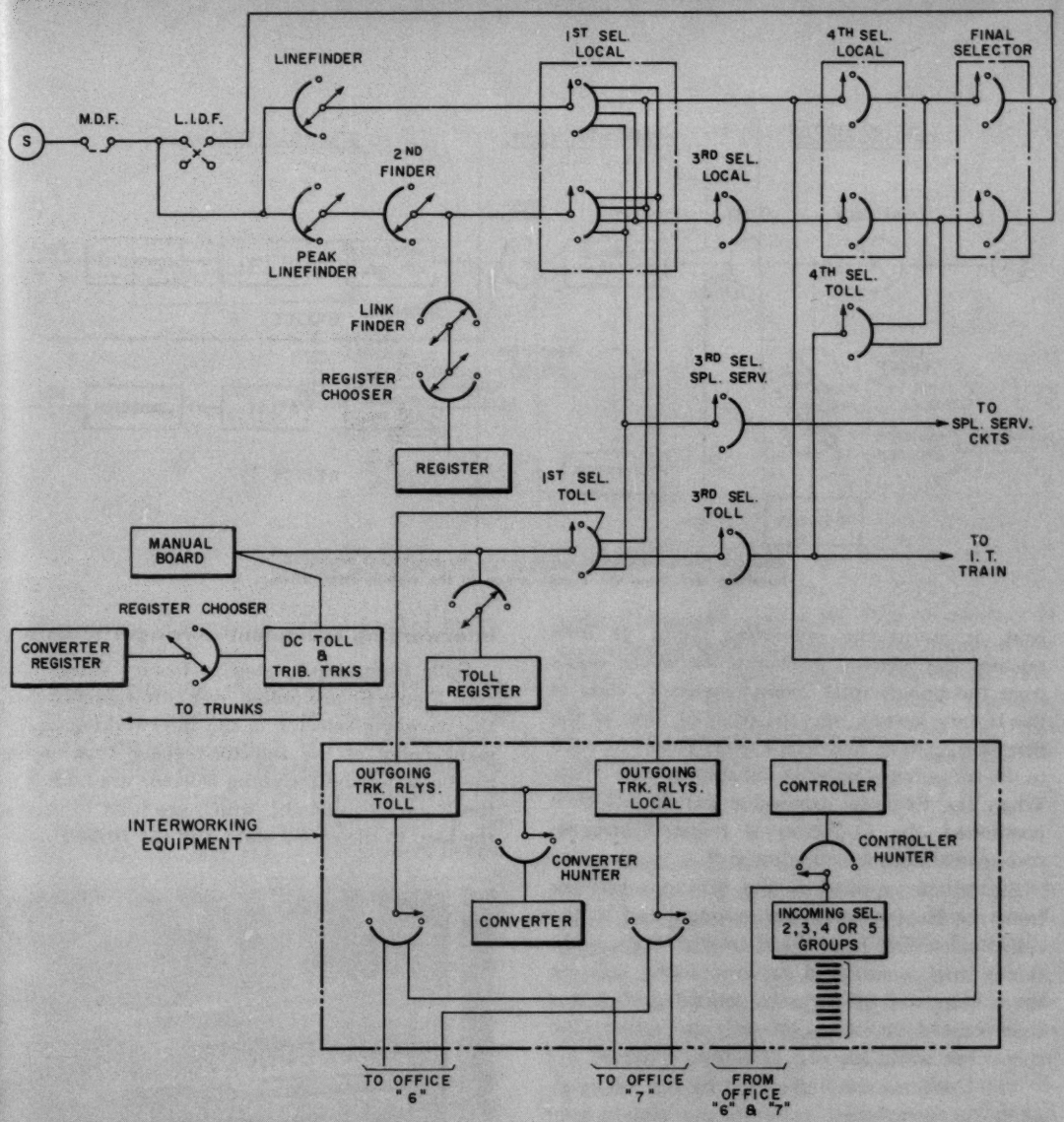


Figure 3. Schematic diagram shows interconnections of Rotary equipment with the interworking equipment, also installed in the Main Office.

registers so that subscribers dialing 74/75 xxx would, until the cutover, reach subscribers through the 54/55,999 group in the Rotary exchange, and thereafter, through the step-by-step equipment. Thus, no subscriber had more than one number-change — and then in only the initial digit.

Since local and toll trains have separate register groups, the strapping was changed to meet the 2000-number change, thus making level 5 available for the calls to the new step-by-step offices.

Interworking Equipment—Rotary to Strowger

A simplified schematic diagram of the equipment required on calls from the Rotary to the Strowger offices is shown in Figure 4. Calls originating in the Rotary units are routed through the register in the normal way. When a step-by-step office code ("6" or "7") is dialed, the register causes the 1st group selector to select the outgoing level (5) and hunt for a free trunk.

The Converter provides revertive impulses to the registers in the Rotary system, and sends forward to the step-by-step office, decimal pulses corresponding to those sent by a dial. It is associated with a trunk during the time required to position the selectors in the step-by-step office. As it returns revertive impulses to the reg-

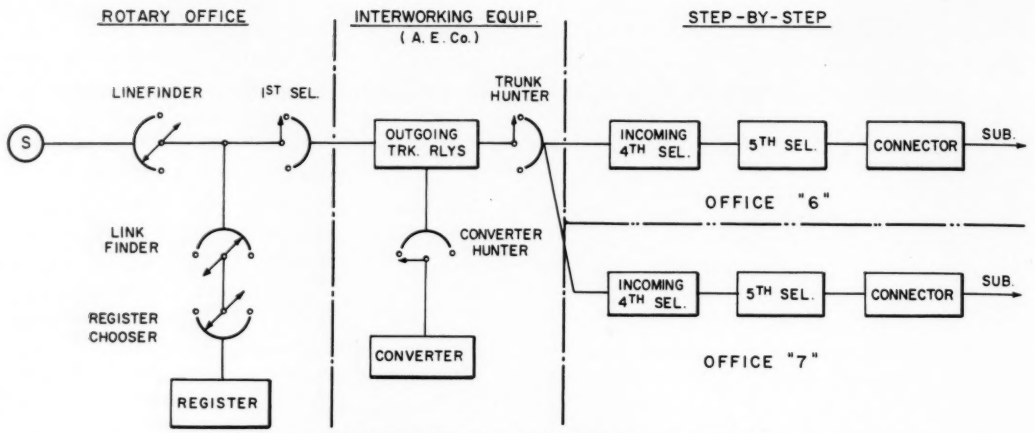


Figure 4. This simplified diagram shows the equipment employed in handling calls from the Rotary office to the step-by-step offices.

ister, it stores the numerical digits. It then releases the register, translates the stored digits from the non-decimal "complementary" code of the Rotary system into the decimal form of the Strowger system, and sends these pulses forward to the incoming selector at the step-by-step office. When the Strowger connector switch has been positioned, the Converter is released and becomes available for another call.

Battery is supplied to the calling subscriber from the Rotary 1st group selector, and to the called subscriber from the connector. Some additional time is required for completing calls to the step-by-step offices, so a simulated click was incorporated in the Converter to satisfy the subscriber while his call is being completed.

The Converters are also used by the toll operators for completing calls to the step-by-step offices. The Outgoing Trunk Relays serve primarily as a holding bridge, permitting use of two-wire interoffice trunks they also control two 25-point rotary switches (Trunk Hunters, see Figure 5) giving each Trunk Relay group access to 25 trunks to each of the new offices. A supervisory lamp on the Trunk Relay group glows dimly if the call has been routed to the #6 office, brightly if it has been routed to the #7 office, so the maintenance man can readily observe to which office the call was routed.

The Converter Hunter connects a Converter to the Trunk Relay group while the call is being set up. The incoming selector is a standard step-by-step selector which makes the "thousands" selection calls to this office, and routes calls through the office in the normal way.

Interworking Equipment—Strowger to Rotary

Calls from step-by-step to Rotary subscribers (see Figure 6) are routed over Strowger switches, the incoming selector in the interworking equipment being of the selector-register type. From the banks of the incoming selector are trunks to the Rotary equipment, which are used to extend the loop to the called station in the Rotary office

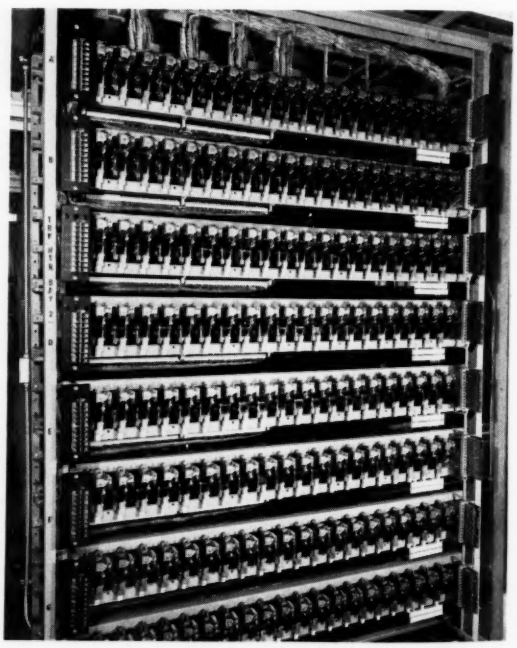


Figure 5. Trunk Hunters (shown) give each Trunk Relay group access to 25 trunks. Similar Converter Hunters and Controller Hunters connect a Converter or a Controller into the circuit while a connection is being established.

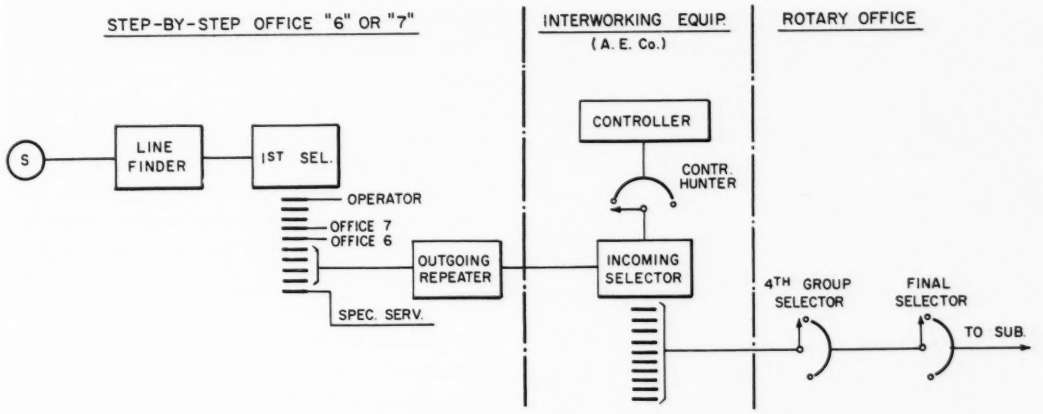


Figure 6. This simplified diagram shows the equipment employed in handling calls from the step-by-step offices to the Rotary office.

under control of Controllers, also located in the Rotary office.

Calls originating in the step-by-step office cause the 1st selector to seize an idle outgoing trunk on the level (2, 3, 4, or 5) corresponding with the office code. (In accordance with the basic trunking pattern of the Rotary system, the directory numbers in the Main office are in the 20,000, 30,000, 40,000, and 50,000 groups; hence, four groups of trunks are now required from each step-by-step office. When 7-digit numbering is introduced, however, this will be reduced to one trunk-group.) The incoming selector responds to the second digit dialed, provides a holding bridge between the step-by-step and the Rotary equipment, and controls the Controller Hunter. It is multipled, with the Rotary 1st and 3rd group selectors, to the brushes of the Rotary 4th selectors, and provides functions equivalent to those performed by the Rotary 1st and 3rd selectors on Rotary-to-Rotary calls.

Extensive regrading of the Rotary 4th group selectors was required to provide adequate outlets from the incoming selectors, on trunks from the step-by-step office.

The function of the Controller Hunter is to connect a Controller to the circuit during the time the call is being set up. The Controller is seized when the incoming selector is operated, and it remains associated with a trunk during the time required to position the Rotary 4th and final selectors. It receives the last three digits from the calling subscriber as normal dial pulses' stores them, and translates them into the Rotary code. The positioning of the Rotary selectors is controlled by counting the revertive impulses and comparing the count with the translated code, in the same manner as the Rotary registers. When the Controller has positioned the final selector, it releases and becomes available for another call.

Intertoll Train

As mentioned above, there had previously been no intertoll train at Lexington. A completely new step-by-step intertoll train was therefore added, coincident with the addition of the Rotary-to-Strowger interworking equipment. It works directly into the step-by-step offices on a decimal-pulse basis. On calls from the intertoll train to the Rotary office, however, Controllers are required—just as on calls from the Strowger offices—except for working into the 4th group toll selectors and final selectors of the Rotary system. For these purposes a Preceding Group selector was provided to supplement the Rotary toll 1st group selector; its primary function is to provide ringing, tones, battery feed and supervision, as does the Rotary toll 1st group selector. To serve the intertoll traffic with minimum delay, a separate group of Controllers are provided for this traffic.

Local calls within the Strowger offices are handled by completely standard step-by-step operation; no special circuits are involved. Similarly, for service between these offices, direct trunks and standard facilities were provided.

Access to special services did not present much of a problem—with the exception of coordinating

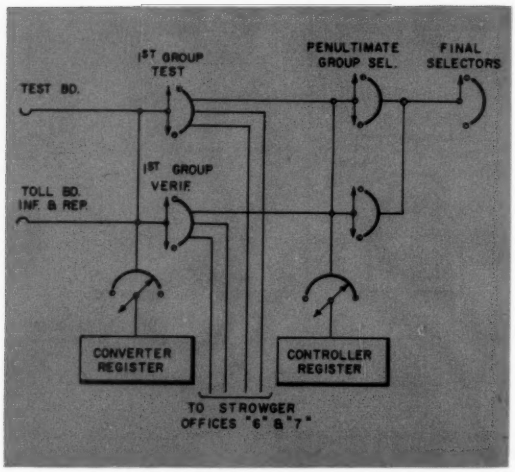


Figure 7. Schematic diagram showing connection of test distributors to the Test and Verification train in the Rotary office.

equipment of different types—but additional special-service trunk equipment was required because of the office growth caused by addition of the new offices. Automatic Electric provided adapters on both ends of these trunks, for converting from 3-wire to 2-wire circuits, and these adapters were connected to the Rotary-type trunk-terminating equipment for the various special services.

Test Facilities

The Rotary equipment is provided with a "holdover" feature which helps in finding faults in the circuitry, by holding the switch train and releasing the subscriber when some fault prevents a call from maturing. Automatic routine test equipment is also provided with the Rotary office; it is a necessity and is constantly used. Automatic Electric has therefore also provided the "holdover" feature and portable test units for the Converters and Controllers.

Test distributors were installed in the new offices and connected to the Test and Verification train in the Rotary office. This did not present much of a problem, as the Rotary test train had two registers associated with it—one to convert key pulses from the test board into dial pulses to work into a centralized register which controlled the group selector and test final selectors by revertive impulses. We bypassed the centralized register and connected directly to the output of the Converter register, and utilized the converted dial pulses to control the test distributor at the step-by-step offices (see Figure 7).

Conclusion

The interworking equipment, and the first step-by-step office ("7"), with a capacity of 10,000 connector terminals, were placed in service in December, 1956, and the second office ("6") was placed in service on March, 1959. Each of these offices has now grown to approximately 8,000 stations, and we are presently planning a third office ("9"), to be placed in service in the near future.

For the same reasons that Strowger equipment was selected for the #6, #7, and future #9 offices, consideration is being given to the eventual replacement of the Rotary office by step-by-step. This would, of course, eliminate the interworking equipment described in this article.

Maurice J. Finn began his communications career in the Signal Corps, during World War II, he was trained and assigned to installation and maintenance with the European Theatre of Operations. He brought this experience to General Telephone Co. of Kentucky in 1946, and after four years as central-office repairman and switchman was promoted to chief switchman in charge of the Rotary equipment decribed in this article. In 1954 he was made Division Equipment Supervisor; since 1958 he has been an equipment engineer.

Lawrence D. Sanson completed his engineering training at Stevens Institute in 1944, and began as engineering assistant at Federal Radio & Telephone Co. Shortly thereafter, he became a test engineer, and in 1949, as supervisor of field installations he came to Lexington to install the Rotary 7A2 equipment. He has remained—first as PBX Supervisor, and since 1955 as equipment engineer. Mr. Sanson was involved in the planning of the Rotary equipment, the Strowger Automatic equipment in various offices, and the interworking equipment described in this article.

Type 60
"HIGH-VOLTAGE" LOADING COILS

By R. O. Stoehr
Automatic Electric Laboratories, Inc.

The many changes in outside plant construction that have occurred in recent years—particularly the substitution of plastic- for paper-insulated cables, and the use of re-enterable splice cases—made it desirable to re-study the design of Automatic Electric loading coils. The study resulted in a new series of coils designed to have dielectric strength compatible with plastic cable installations and to be suitable for use in re-enterable splice cases (see Figure 1) as well as in strand-mounted containers. These new "Type 60" coils are "potted" against moisture, and are capable of withstanding a 10 kilovolt pulse between windings and a 20 kilovolt pulse between windings and the mounting stud, or ground. The Type 60 coil is designed to meet all of the REA (Rural Electrification Administration) requirements.

Coil Design Criteria

Loading coils must be designed to provide minimum inductance unbalance between windings, in order to introduce equal amounts of inductance into each conductor of the transmission pair without resulting in inductive coupling losses. The total effective winding resistance must be at a minimum also, so as not to introduce appreciable resistance loss to the line, and the mutual capacitance between the windings must be a minimum so as not to add additional capacitance. For minimum winding resistance, a high core-permeability is desirable. For maximum flux concentration through the windings, and in a manner such as not to disturb adjacent circuits, a toroidal core is required. This core is desired for maximum permeability, consistent with minimum core losses; it must be magnetically stable over a wide temperature range and must provide a minimum of frequency distortion.

Over the years, various materials have been used for loading-coil cores, including iron, permalloy, and more recently, molybdenum-permalloy. Polybdenum-permalloy is about 80% nickel, 2% molybdenum, and 18% iron. This material, in powder form, is annealed and coated with an inorganic insulating material, and then formed, under high pressure, into a toroidal shape. Sub-

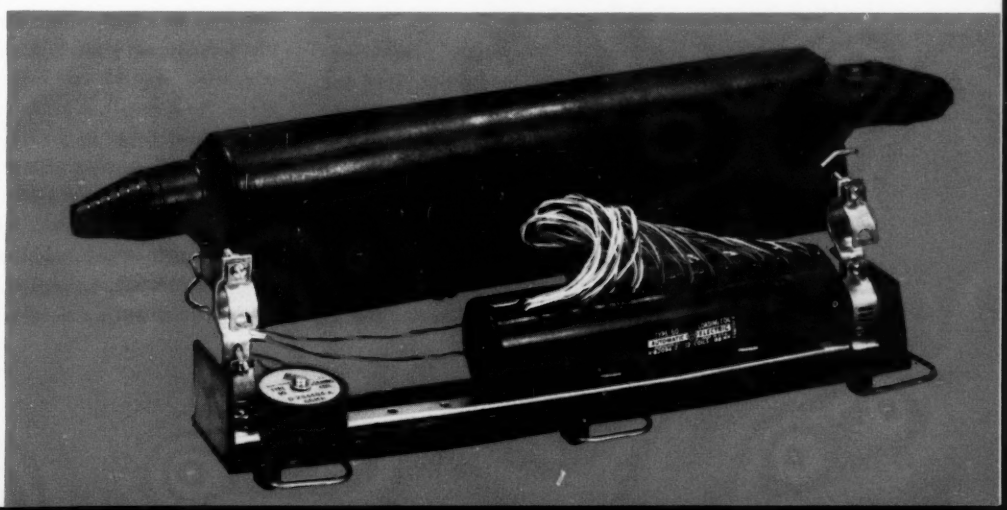


Figure 1. An individual (1-coil) and a multicoil (12-coil) Type 60 loading coil unit have been assembled, in the field, into this Neoprene "re-enterable" splice case.

Figure 2. Three stages in assembly of an individual Type 60 loading coil. Left, the wound coil; center, after rubber-dipping; right, in the plastic case.

sequent hydrogen annealing, and coating with an enamel or epoxy resin, completes the core. Molybdenum-permalloy has the desirable characteristics of good magnetic stability to d-c magnetization, low eddy current and hysteresis losses, high electrical resistivity, and quick return to its non-magnetized state.

For years, Automatic Electric Company has produced high-quality voice-frequency loading coils. These coils, known as Type 58, are being extensively used in the field, but are furnished only in sealed, pressurized, steel containers for pole mounting, underground mounting, or direct burial. These steel cases are supplied with a paper-lead cable stub, the end of which is sealed and valved to permit drying and pressurizing.

The present trend in outside plant design indicates the increased need for re-enterable splice cases which can be used where few loaded pairs are required, and for strand-mounted, rather than pole-mounted, multicoil cases where more coils are needed. This suggests the need for individually- or group-potted coils for use in these splice cases, and the use of the more desirable lead container for the larger multicoil cases. Furthermore, since the trend is toward plastic cable, a more compatible cable stub than paper-lead is required on the multicoil cases.

High-Voltage Coil Design

Because of the superior dielectric properties of plastic cables, changes are also taking place in outside plant protection. It is felt that, since the plastic cable is so much better, the loading coils should not be the weak link. Consequently the need is for loading coils which are capable of withstanding the momentary higher-voltage pulses compatible with plastic cable, and which would not have to be individually protected. The potting of Type 58 loading coils upgrades them from a 1500-2500 VDC breakdown level to about 4000 VDC. This is not adequate for present-day requirements; furthermore, high-voltage test data are so erratic that an entirely new design-approach was required. An investigation was therefore begun to determine the weaknesses of loading coils at higher voltages.

Initially, the coils were placed in a styrene shell, and potted with a polyester casting resin. High-voltage breakdown tests of these coils revealed the breakdown path to be generally either over or under the winding spacers. Spacers of various thicknesses, as well as various materials, were tried with little improvement. The main factors that provided definite improvements were increased thicknesses of wire enamel and an increase in surface distance between the windings. Tests further revealed that the parameters of the

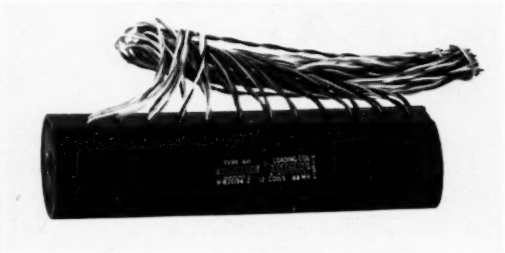


Figure 3. A typical potted assembly of Type 60 loading coils; this unit contains 12 coils.

coils were subject to considerable change during temperature-conditioning, and that during humidity-conditioning, moisture travelled into the coil along the lead-out wires, to the extent that the unit failed completely.

The shift in coil parameters was not always predictable, and was further subject to environmental temperature changes and aging. It was felt that to insure a precision coil which retained its tolerances during field operation, the coil windings should be isolated from the potting resin. As a result, a rubber-dipping operation was introduced prior to potting. This coating acts as a conformal coating around the coil, serving both as a moisture barrier and a resin barrier. In addition, as a result of this coating, the coil is protected against the mechanical shock that may be encountered during shipping or installation. To prevent entrance of moisture into the unit,

the splices of the coil leads and lead-out wires were bared, which permitted the casting resin to directly contact the metal, thus assuring a moisture dam. Finally, to assure an excellent bond to the wire, and to provide a tougher unit, not subject to resin-cracking and the entrance of moisture, an epoxy casting resin was substituted for the polyester resin originally tested.

The required thicknesses of wire enamel and core enamel resulted in the design of a core that is larger both in outside and inside diameters than that used for the Type 58 coil. However, this core is thinner (measured on a line parallel to the axis of the center hole), so that more coils can be "stacked" into a re-enterable splice case of a given length. The additional core diameter permits the use of wire that is not only more heavily enamelled, but also of a larger gauge, thus attaining minimum d-c resistance of the coil windings; this parameter is one of the main contributors to the total effective winding resistance. To assure maximum breakdown strength between the windings and the metallic core, the core is specially finished with multi-coatings of electrical-grade baking-enamel.

Prior to winding, the cores are graded in terms of permeability, so that each core, in combination with a given number of wire turns, accurately achieves the desired characteristics, within very close tolerances. Coils are wound in two segments, separated by spacers. This winding method introduces less mutual capacitance between windings than other methods, and simplifies the winding operation. Every coil is closely inspected both for correct inductance and effective resistance, and for minimum inductance and resistance unbalance between the windings; turns are removed as required to produce a high-precision coil. Finally, the coil is rubber-dipped; it is then ready for assembly into an individual unit or into a multi-coil potted assembly.

Figure 2 illustrates the sequence of assembly of an individual coil assembly.

Coil Assemblies

The rubber-dipped coil, with color-coded lead-out wires attached, is placed in a high-impact modified-styrene shell. The shell is designed to permit the potting resin to completely envelop the coil. The lead-out wires are brought out through the circumference of the shell, so several coils may be stacked closely together, as in a 3-coil group. Such a group may be assembled with all coils facing in the same direction, or alternately face-to-face and back-to-back; the design inherently maintains a crosstalk loss greater than 90 db between adjacent coils.

Multicoil units are made by stacking the required number of dipped coils on insulating tubing. Crosstalk disks and insulators are placed between the coils, and the windings of alternate coils are staggered at a 45° angle with respect to adjacent coils, as described above. The complete stack is then placed inside a plastic shell which, in turn, is filled with an epoxy potting-resin. The lead-out wires are brought out through a slot which extends the entire length of the shell; thus, the leads are not only color-coded, but are also position-coded. Multicoil assemblies are made in units of 6, 12, 18, and 25 coils, corresponding to the conductor pairs in even-count plastic cable (Figure 3).

Lead- and Steel-Case Assemblies

Type 60 loading coils in quantities of 25, 50, 75, 100, 125 and 150 coils, are also available in

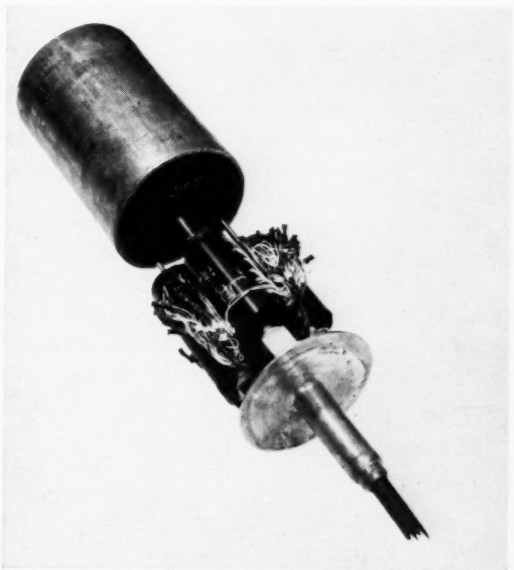


Figure 4. Method of assembling Type 60 loading coils into a lead case.

lead and in steel cases, with plastic cable stubs. To meet the high-voltage requirements, the proper number of potted coil groups and individual coils are assembled to the case cover plate (Figure 4), the plastic cable stub passes through a lead sleeve and enters the container through the center of the cover plate, and the portion of the cable jacket inside the lead sleeve is removed and the conductors subsequently surrounded by an epoxy casting-resin which serves as a moisture barrier, and prevents moisture in the cable stub from entering the case. Since all coils are already adequately encased by a potting resin and are suitable for direct external use, the case assemblies are shipped dry—there is no need to place them under pressure. The case assembly design is such as to withstand 20 kilovolts applied instantaneously between cable pairs and case.

Methods of Mounting

The lead-case assemblies are intended for strand mounting, i.e., direct-lashing to an aerial cable in mid-span. This makes it possible to load directly at the point where two cable lengths are spliced; it minimizes cable splicing, and eliminates the problem of moving a loading coil assembly when pole replacement is required. Steel cases can also be provided, however, for direct burial, or with brackets suitable for installation on poles or in vaults.

As mentioned before, individual coils and multi-coil units can be used in splice cases, terminal cases, and for direct splice mounting (Figure 1). All units are provided with stainless steel hardware. The individual coil can be mounted in a re-enterable splice case by the screw through its center; or it can be mounted in the terminal case by means of a special hook bracket. Three-coil groups and multicoil units are provided with stainless steel U-clips, that greatly facilitate the installation of these assemblies into crowded splice cases; they permit the installer to first fasten the clips to the case, and then snap the coil assembly in place. Furthermore, the clips permit the installer to rotate the coil assemblies so that the lead-out wires are easily accessible. Also, in some splice cases it is possible to slide the coil assembly, in the clip, to the extreme end of the case, thus providing additional room for extra coils or another terminal block.

Conclusion

Type 60 loading coils are designed to satisfy the needs arising with the expanding use of plastic cable and re-enterable splice techniques. These coils are the same precision quality as the popular Type 58, but in addition they offer high dielectric strength (which permits economies in plant protection methods) they have less total effective resistance, and they are suitably encased to permit direct external use in splice and terminal cases.

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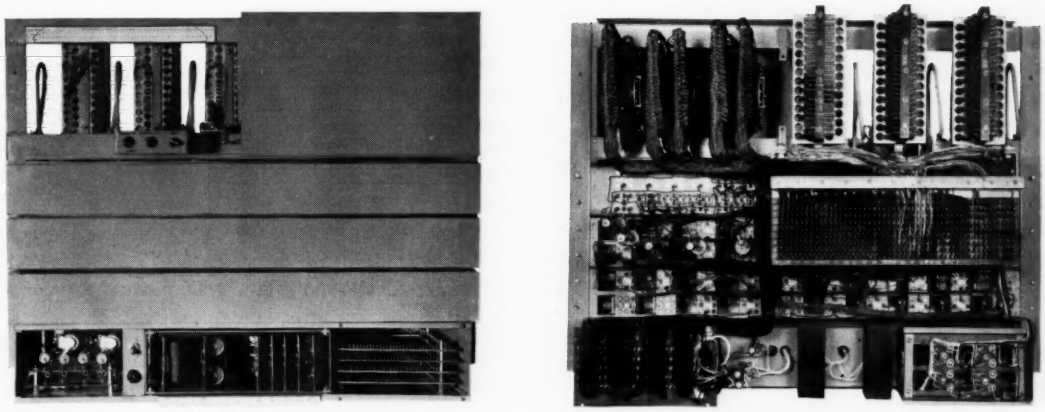
AN EXPERIMENTAL SATT TABULATOR

Using Ferrite Cores

By H. M. Winters
Automatic Electric Laboratories, Inc.

This paper was presented by Mr. Winters at the A.I.E.E. 1961 Winter General Meeting, New York, N.Y.



A. Front View B. Rear View

Figure 1. The Experimental Tabulator

An experimental Automatic Toll Ticketing Tabulator was constructed, utilizing ferrite cores as data storage elements in lieu of codel relays. The unit was installed in a laboratory automatic toll ticketing system, and its performance evaluated under simulated operating conditions. Results of the tests indicated that the ferrite-core Tabulator will adequately perform all the functions of the relay-operated unit it replaces.

We are fast approaching the era of the electronic telephone central office, and automatic toll ticketing systems of the future will require improved techniques to remain compatible with the telephone systems now in the formative stages. As a step in this direction, a study was undertaken at Automatic Electric Laboratories to investigate data-storage techniques which could be applied to various stages in Strowger Automatic Toll Ticketing (SATT) equipment. The Tabulator was chosen for the initial study since it provided a simple approach for the study of data-storage techniques without disturbing the inner workings of the SATT system.

In a SATT system the Tabulator functions to store data pertinent to billing a toll call. At the completion of the toll call the Tabulator accepts data from the ticketer in a fixed sequence. It then "reshuffles" the data into a particular desired sequence and feeds it into permanent storage (in this case, punched paper tape for computation

by the data-processing equipment which sums up and calculates the monthly subscriber toll bill.)

The present SATT Tabulator utilizes codel relays for storage of data — each codel relay being actually a cluster of four relays. A project was initiated to investigate a technique of data-storage in the Tabulator, employing ferrite cores as storage elements. An Experimental Tabulator (shown in Figures 1A and 1B) was developed, which is compatible with the other components of the SATT system and performs all the functions of the relay-operated unit it replaces. No attempt was made to construct an all-electronic unit, and the resulting ferrite-core Tabulator is a hybrid system, employing both electronic and electromechanical components. Electronic circuitry is employed only in those circuits associated with "writing in" and "reading out" the ferrite cores; all control functions are performed by relays.

A restriction placed on design of this unit was that, in addition to reliability and compatibility, economy would also be an objective.

This paper is concerned with the requirements, the circuits and the design philosophy connected with development of the experimental model.

System Operation

When a toll call is made through an office utilizing SATT equipment, a ticketer is assigned to receive and store information pertinent to the call. At the completion of the toll call, the ticketer seizes an idle Tabulator and "spills" these data into the Tabulator's codel relays (in the case of the subject Tabulator, the data are written into the ferrite cores). These data may include:

a) Caller's number
b) Area and number called
c) Clock time and date
d) Clock time at end of call
e) Conversation duration
f) Rate
g) Ticketer's number
h) Tabulator's number
i) Toll charges

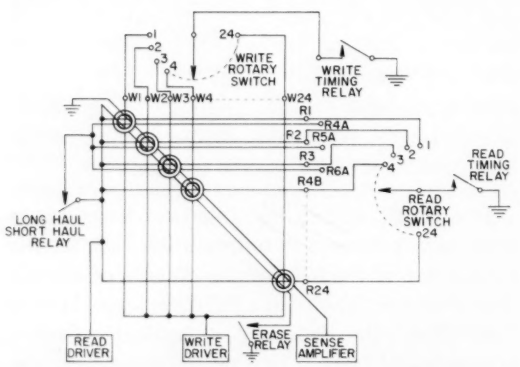


Figure 2. Functional diagram of ferrite-core Tabulator

Information is received through a four-level rotary switch. The wiper arm at each level of this rotary switch is connected to ground by a timing relay controlled by the ticketer. The leads from the rotary switch are connected to the ferrite-core memory "write" windings. There are four memory planes, designated W, X, Y and Z, respectively — one plane being associated with each level of the rotary switch (Figure 2 diagrams one such memory plane). There are 24 cores in each plane, a total of 96 cores in all four planes. A write driver is associated with each memory plane, while a single Read driver is common to all four planes. Each memory plane has a sense amplifier associated with it.

As the rotary switch is stepped sequentially through its 24 positions, the cores may or may not have data switched in, depending on the presence or absence of a ground mark on the wiper arm. At the completion of the write cycle, the data is transferred, in a permuted sequence, to the tape perforating equipment.

Information read-out is accomplished identically to the method of writing. A single-level rotary switch simultaneously reads the four planes, sequentially interrogating the 24 cores in each plane; correspondingly located cores in the four planes are read out simultaneously. A lead from a terminal on the Read rotary-switch threads through the four cores in series to the Read driver. There are 27 of these wires, the extra three wires being required for the special long haul-short haul functions, described later. The 27 wires are interconnected by a long haul-short haul relay for proper storage arrangement of information.

The storage of information by accidental means is precluded by addition of an extra winding and an Erase relay. The Erase winding

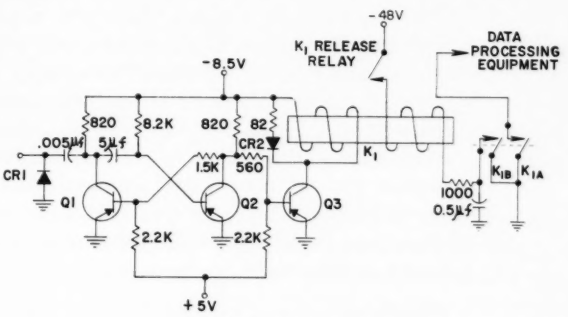


Figure 3. Circuit of Sense Amplifier

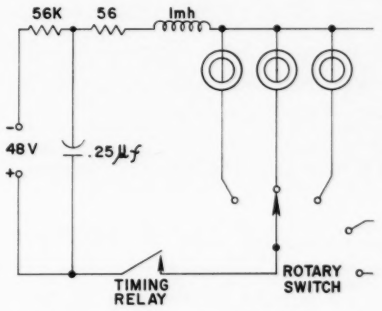


Figure 4. Pulse-forming network for driving ferrite cores

threads through all 96 cores in series from the Read driver to the Erase relay. The Erase relay operates just prior to the start of the "write" cycle, putting a momentary ground on the Erase winding. Thus all the cores are read out or erased, allowing the "write" cycle to start with a clean slate.

Data stored in the cores are used to operate a control relay which passes the information on to the data-processing equipment.

Circuit Description

Economy without the sacrifice of reliability was an important design consideration. To reduce the number of transistors used in the sense amplifiers, a ferrite core was chosen that would give a substantial output voltage on switching. The sense amplifier receives a one-volt (peak), four microsecond pulse which is "stretched" to 40 milliseconds by a monostable multivibrator circuit. This pulse-stretching is required to insure compatibility between the high speeds of the electronic circuits and the relatively slow speeds of the relays in the associated equipment. One amplifier is associated with each memory plane, and the output of the sense amplifier is used to trip a self-latching relay. For ease of maintenance, the sense amplifiers are mounted on four printed-wiring cards.

Straightforward circuity (see Figure 3) is employed in the sense amplifiers, with Q_1 and Q_2 comprising the monostable multivibrator used to "stretch" the input pulse. The multivibrator drives an amplifier, Q_3, which switches current to operate relay K_1. This amplifier also performs an important buffer function by isolating the multivibrator from the transient spikes generated in the solenoid windings of K_1.

CR_2 protects Q_3 from excessive collector-to-emitter voltages caused by switching transients resulting from the high inductance of the relay field.

CR_1 functions to clip the pulses arising during the write-in cycle. Although these pulses are not of the proper polarity to trip the multivibrator circuit, a transient spike occurs at the trailing edge which could trigger the multivibrator.

Since the cores are selected at a low operating speed by a mechanical switch, an economical and reliable means of driving the cores with a pulse-forming network (PFN) presents itself. A capacitance is an excellent current-source when operated in a long duty-cycle system; thus, by selecting proper parameters of damping resistance, inductance, and capacitance, it is possible to generate the required pulse without any active elements in the drive circuitry. The circuitry for such a driver is shown in Figure 4. During a relatively long charging period of approximately 0.1 second, a small current flows from the exchange battery through a high resistance, to charge the capacitance. When the PFN is discharged through the low-impedance cores, a high-amplitude current pulse of short duration is generated. Peak amplitude of this pulse is 600 milliamperes; pulse duration is approximately four microseconds. Four separate drivers are employed to write data into the cores, and a fifth driver is used to interrogate the four planes simultaneously.

Two minor problems were encountered when designing this unit. For the unit to be directly

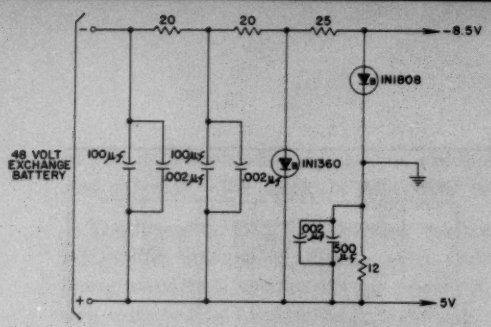


Figure 5. Power supply for ferrite-core Tabulator

interchangeable with the relay-operated Tabulator, it was necessary to utilize the 48-volt exchange battery as a source of primary power. Since it was desirable to use low-cost transistors, it became necessary to reduce the 48 volts to a lower value. A simple voltage-reduction circuit utilizing resistances and Zener diodes for regulation appeared most suitable for the unit. Even though considerable power (approximately 20 watts) is dissipated in the voltage-dropping resistances during the operating period, the simplicity of this method offers a significant advantage over the more complicated circuitry of an inverter. A set of contacts disconnect the power supply during idle periods, so power is required of the exchange battery during only the short periods of operation.

A cascaded system of regulation is employed, with one Zener regulating at the 24-volt level and a second Zener regulating at the 8.5-volt level. This circuit is shown in Figure 5. With this method, excellent voltage regulation is obtained; voltage variation is less than 0.2 volt from no-load to full-load conditions, which far exceeds the requirements of the system.

A second problem lay in the ever-present transient voltages in the exchange 48-volt system. These arose from the many relays of the telephone exchange; quite often the transients were very severe — in fact, spikes with amplitudes in excess of 100 volts have been noted. The effect of these transients was to trigger the multivibrator spuriously. These adverse effects were eliminated by the use of large capacitances in the power supply system.

Development of the Electronic Tabulator was, of course, a team effort. J. M. Bernstein was coordinator of the project, and was intimately associated with design of the memory unit. W. A. Reimer was largely responsible for the packaging of the Tabulator, in its final form.

Conclusion

The completed ferrite-core Tabulator was installed in a laboratory SATT system and tested under simulated operating conditions. Proper operation was observed under fluctuating voltage conditions of the exchange battery, with voltages ranging from 47.5 volts to 51 volts. Satisfactory operation was also obtained at ambient temperatures up to 60°C. The unit exhibited a complete immunity to variations in transistor characteristics and, within limits, to transistor type.

Results of testing, to date, indicate that the unit is completely reliable and that ferrite cores can be used in a future high-speed SATT system. Although this first engineering model of the Tabulator was successful, it is by no means representative of an ultimate model. It does, however, point the way to improvements in size, circuitry and more efficient utilization of primary power.

H. M. Winters graduated from Illinois Institute of Technology in 1959, with the degree of B.S.E.E. He joined the Research Department of Automatic Electric Laboratories, Inc., where, in addition to the work that resulted in the above article, he has conducted investigations into the possible application of electroluminescence to telephony. Mr. Winters is at present investigating various types of magnetic logic circuits, and possible applications to telephone switching. He is a member of Tau Beta Pi, Eta Kappa Nu, the Institute of Radio Engineers, and the American Institute of Electrical Engineers.

THE TRC-2 TRANSISTOR RINGING CONVERTER

By Douglas J. Suda
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and

Robert F. Winkler
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The Leich Electric Company Type TRC-2 Transistor Ringing Converter is a d-c to a-c converter which furnishes low-frequency power used to ring a subscriber's telephone. It operates from 48-volt exchange battery and provides five frequencies of the decimonic (20, 30, 40, 50 and 60 cycles), harmonic (16⅔, 25, 33⅓, 50, and 66⅔ cycles), or synchromonic (20, 30, 42, 54, and 66 cycles) series. It is capable of providing 25 watts of each frequency (125 watts for a five-frequency converter), and a sufficient amount of adjustable ring-back tone.

Figure 1. The TRC-2 Ringing Converter is designed to mount on either a 19- or a 23-inch relay rack.

A cabinet (see Figure 1), 10½ inches high, 18 inches wide, and 11 inches deep, houses the five frequency units and mounts on either a 19-inch or a 23-inch relay rack. Each frequency unit measures 10½ inches high, 3½ inches wide, and 11 inches deep, and consists of separate plug-in components, as an aid to quick and easy maintenance.

Circuit Description

Figure 2 is a block diagram of any one of the frequency units. For simplification, the circuit has been divided into the following parts:

A. Input filter
B. Input voltage regulator
C. Oscillator
D. Third-harmonic reduction circuit (in 16⅔- and 20-cycle units only)
E. Driver circuit
F. Output circuit and filter
G. Load limiter

Input Filter

This is provided to prevent high-frequency harmonics, produced by the Converter, from being superimposed onto the supply battery (if these harmonics were not suppressed, they would interfere with telephone transmission). The filter consists of a choke and a capacitor.

Input Voltage Regulator

As will be shown later, the frequency of the oscillator is directly proportional to the voltage applied. It is therefore important that the d-c input be of constant voltage. This is regulated by the circuit shown in Figure 3. Zener diode ZD1 has a higher Zener voltage than Zener diode ZD2. With variations in battery voltage, the potential at point "a" will vary slightly. This slight variation is applied to ZD2, which results in the potential at point "B" being very stable, regardless of large changes in battery voltage.

Thermistor TH1 is connected across R2 to

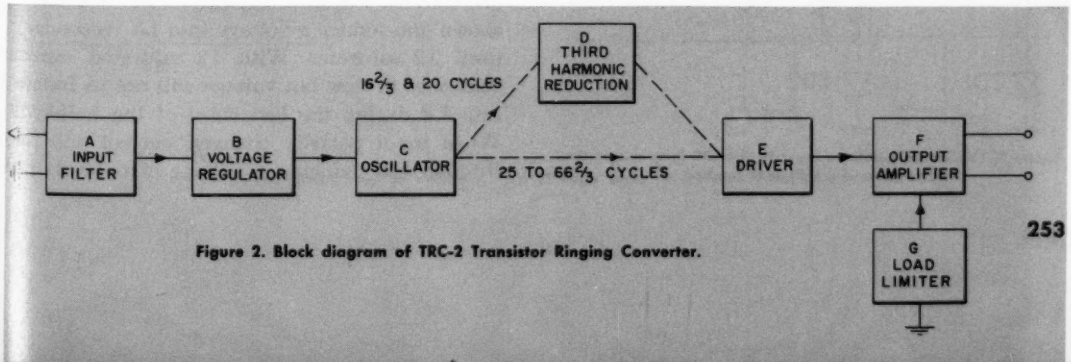


Figure 2. Block diagram of TRC-2 Transistor Ringing Converter.

compensate for the temperature coefficient of ZD2. The net result is a regulator capable of providing constant d-c voltage, irrespective of large variations in supply voltage and ambient temperature values.

Oscillator

The oscillator circuit consists basically of a toroidal coil with a square-hysteresis-loop core, and two transistors. Figure 4A shows a simplified circuit and a B-H curve of the core material used in T1. Figure 4B shows the core flux (ϕ) and voltage (e) induced in the secondary winding of T1 with respect to time.

Operation

The transistors operate on an ON-OFF basis, to obtain a square-wave a-c output voltage from a d-c source. The transistors are switched ON and OFF by control windings L1 and L4. When one transistor is ON (conducting), the other is biased OFF.

Referring to Figure 4A, assume that Q1 is switched ON. This allows current to flow through L2 in the direction shown, causing a voltage of polarity shown to be induced in each winding. Q1 remains ON and Q2 remains OFF while current continues to flow in L2. Flux increases in the core until it abruptly saturates. When this occurs, the induced control voltages fall to zero and both Q1 and Q2 are turned OFF. With no current to produce flux, the magnetic field starts to collapse, changing the direction of $d\phi/dt$ (Figure 4B), and the induced voltages. Reversal of the voltages in control windings L1 and L4 causes Q1 to be biased OFF and Q2 to turn ON. Now current flows through L3 and transistor Q2, causing voltages, of polarities opposite to those shown, to be induced in all windings. This current continues to flow until the core saturates again, completing one cycle of operation.

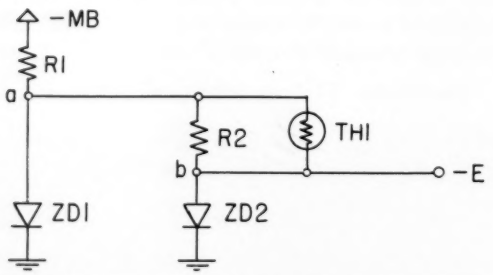


Figure 3. This circuit regulates input to the TRC-2, to assure that a constant d-c voltage is applied.

From Figure 4B it can be seen that flux ϕ changes from $+\phi m$ to $-\phi m$ (ϕm being saturation flux) during one half cycle T/2 seconds, where T is equal to the period of one cycle. Thus, for one half-cycle a change of $2\phi m$ occurs. The average induced voltage is equal to the total flux change divided by the time of flux change,

$$\text{or:} \quad e = \frac{2N\phi m}{T/2} 10^{-8}$$

$$\text{where:} \quad T = \frac{1}{F}$$

$$\text{and:} \quad \phi = BA$$

$$\text{combining:} \quad e = 4NBAF \cdot 10^{-8} \qquad (1)$$

Equation (1) shows that the frequency is directly proportional to the applied voltage. Therefore, it is very important that the input voltage remain constant for all variations in battery voltage, to maintain good frequency stability.

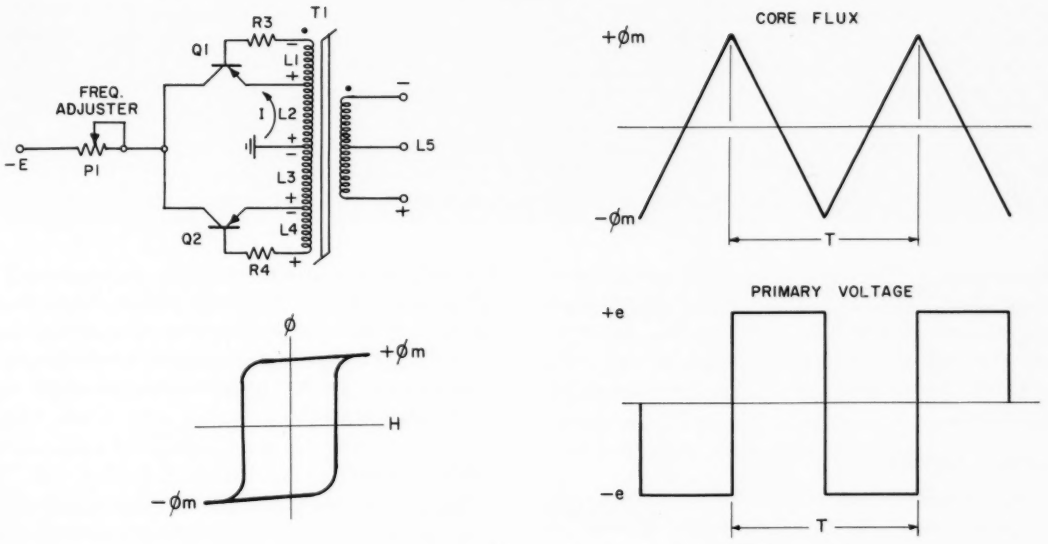
Third-harmonic Reduction

When power is generated in the form of a symmetrical square wave, the odd harmonics are naturally present. If the power is to be used for standard frequency-selective bridged ringing, it is necessary to reduce the third-harmonic of some frequency units, to prevent cross-ring. For example: the third-harmonic of 16⅔ cycles is 50 cycles. In the harmonic series of frequencies, a 16⅔- and a 50-cycle ringer are frequently bridged across the same line. If the third-harmonic of the 16⅔-cycle unit were not reduced, then both 16⅔- and 50-cycle ringers would ring when the 16⅔-cycle frequency was applied. The same is true of 20- and 60-cycle ringers.

Operation

Figure 5A shows the circuit used to remove the third harmonic from the output of the 16⅔- and 20-cycle units. Transformer T2 has a square-hysteresis-loop core and is designed to saturate in approximately two-thirds the time of one half-cycle.

Assume an input polarity as shown in Figure 5A. Current will flow through L1 in the direction shown and induce a voltage into L3 (secondary) until T2 saturates. With T2 saturated, current continues to flow but voltage will not be induced into L3 during the last third of the half-cycle, When input polarity changes, current will flow through L2, inducing a voltage of opposite pol-



A Figure 4. The oscillator circuit used, and its characteristics. B

arity into L3. Again T2 saturates, preventing the last third of the half-cycle from being induced into L3. By removing one-third of each half-cycle the third harmonic has been eliminated.

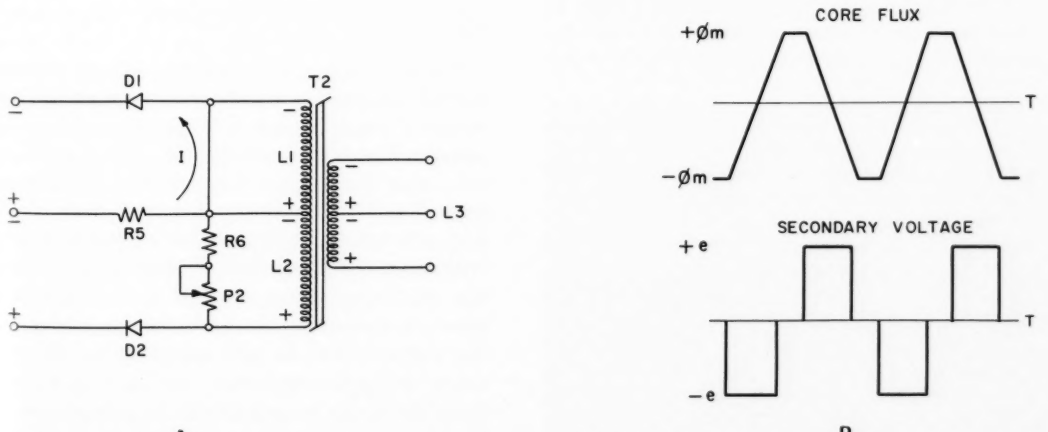
Diodes D1 and D2 are used to prevent the collapsing field of T2 from inducing a large amount of voltage into L3 when current ceases to flow through windings L1 or L2.

Potentiometer P2 is used to adjust the amount of current flowing through T2, thus adjusting the amount of waveform that is removed from each half-cycle.

Driver Circuit

The driver stage is used to isolate the oscillator from the output, preventing load changes from affecting oscillator frequency stability and output voltage.

Two types of driver stages (Figure 6) are used in the Converter. Those frequency units with the third harmonic removed (i.e., 16⅔- and 20-cycle) use a driver (Figure 6A) which has resistance bridged across the output to prevent induced voltages from distorting the waveform (such distortion would cause the third-harmonic



A B

Figure 5. The circuit used in the 16⅔- and 20-cycle units, to remove the third-harmonic.

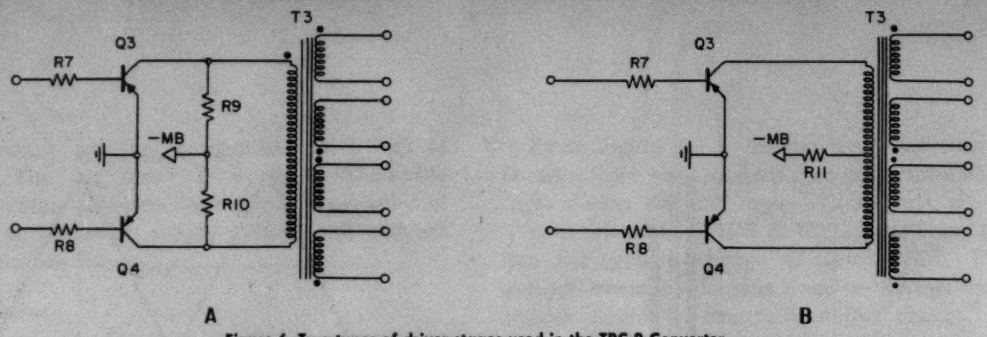


Figure 6. Two types of driver stages used in the TRC-2 Converter.

to reappear). The other frequency units use a conventional push-pull circuit with center-tapped transformer (Figure 5B). Resistor R11 prevents induced voltages in series with the battery voltage from "punching through" the non-conducting transistor.

Output Circuit

The output circuit (Figure 7) is a bridge-type amplifier in which two transistors operate in series at a given time. This prevents destructive breakdown of the non-conducting transistors by battery voltage (plus any induced voltage across the output transformer primary).

Operation

Assume an input polarity from the driver as shown. Transistors Q5 and Q7 are biased ON while Q6 and Q8 are biased OFF. Current flows from ground through the output transformer primary as shown. When incoming polarity from the driver reverses, Q5 and Q7 turn OFF and Q6 and Q8 turn ON. This causes current to flow from ground through the output transformer in the opposite direction. Thus, a-c is induced through the transformer as the cycles are repeated.

Choke L2 and capacitor C2 serve as a filter to reduce the higher-frequency harmonics inherently present in a square wave. These harmonics, if not filtered, would cause crosstalk between cable pairs when ringing out onto a line. Also, these harmonics are used as ringback tone and, if not filtered, would provide an excessive amount. R12 and R13 are the two resistors used to adjust the ringback-tone level.

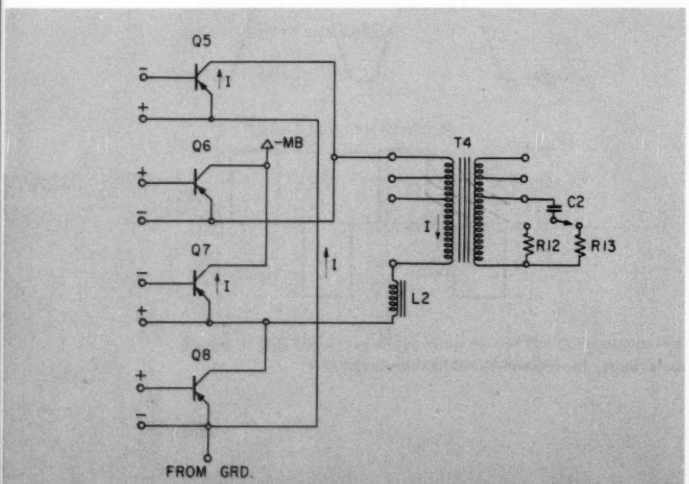


Figure 7. Two transistors, operating in series at the same time, act as output limiter, to prevent damage to transistors.

Load Limiter

To protect the Converter from damage when ringing into an overload or a short circuit, a self-protecting feature is incorporated in each frequency unit. This feature permits the unit to be overloaded for an indefinite length of time without damage.

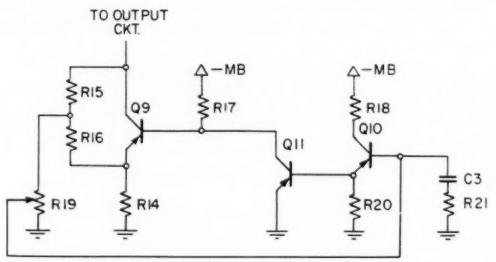


Figure 8. This load-limiting circuit enables a frequency unit to carry an overload for an indefinite period.

Operation

Figure 8 shows the limiting circuit. Under normal conditions, all the d-c required by the output circuit is supplied through the small resistor, R14, and transistor Q9. Increasing load will cause the current through R14 to increase proportionally. A portion of the IR drop across R14, selected at R19 (Q9 is fully conducting and IR16 is zero), is applied to the base of Q10. When this negative voltage reaches a predetermined value, Q10 starts to conduct, causing current to flow through R20. As load increases, the IR drop across R20 also increases, causing Q11 to conduct; this starts to turn off Q9. Now load current flows through R14, R16, and R15. Because R16 is slightly greater than R14, the negative poten-

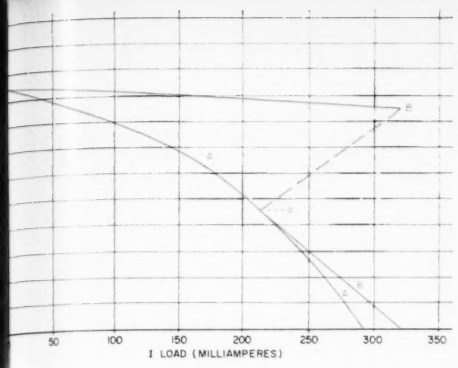
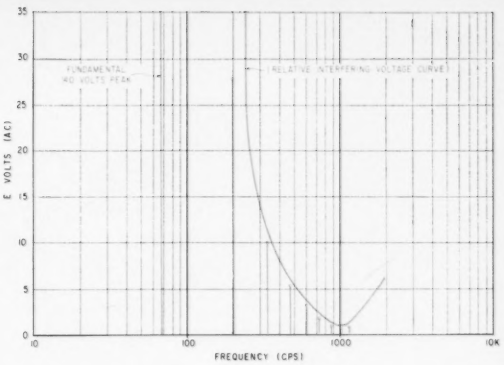


Figure 9. Comparison of the output regulation provided by the built-in cutoff with that provided by a ballast lamp.

Figure 10. Typical "interfering voltage" curve of 66⅔-cycle output waveform shows maximum harmonic voltages permissable at each frequency. Vertical, colored lines indicate actual voltage measured at each frequency.



tial on the base of Q10 is increased, causing Q9 to continue cutoff until all the load current flows through R14, R15, and R16; Q9 is then fully turned off. The IR drop across resistors R14, R15, and R16, subtracted from the battery voltage, equals the voltage applied to the output circuit. Thus, when the output is a short-circuit, nearly all the battery voltage appears across R15. During overload, the base of Q9 is more positive than its emitter; this keeps Q9 fully cut off, preventing damage in the output circuit.

Reducing the load causes the negative potential on the base of Q10 to become less negative. When this potential falls below approximately −.5 volt, Q10 starts to turn off, causing Q11 to begin to turn off. Q9 starts to conduct and, taking load current, causes Q10 to further turn off. This process continues until the output voltage restores and Q9 is fully conducting.

By adjusting (by means of slide-wire resistor R19) the negative potential applied to the base of Q10, the frequency unit can be set to cut off at a predetermined load value.

Characteristics

The cutoff feature built into the Leich Converter eliminates the need for output fuses or ballast lamps, and provides improved operation. Curve A in Figure 9 shows the output regulation provided by using a ballast lamp; curve B shows the regulation provided by the built-in cutoff feature. Both have the same no-load voltage, and as load is increased the voltage of the ballast-lamp-protected unit decreases rapidly, due to the IR drop across the lamp. Note that at point "a" (just after the frequency-unit is cut off) the output voltage regulation of the frequency unit with the cutoff feature approximately follows the regulation curve of the ballast-lamp-protected unit. Therefore, the cutoff feature offers the same protection as obtained by using ballast lamps, but provides better regulation.

Figure 10 is a harmonic analysis of the 66⅔-cycle output waveform and a relative "interfering voltage" curve — that is, the maximum allowable harmonic voltage permitted at each frequency. Harmonic voltages in excess of these values would cause noise to be coupled into adjacent cable pairs during ringing.

Conclusion

The Leich Electric Company Type TRC-2 Transistor Ringing Converter is a static device which requires little or no maintenance. Each frequency unit is capable of supplying more than its rated load, plus a sufficient amount of audible ringback tone. Its design, generating a square wave, eliminates the need for transistor heat sinks, thus resulting in more efficient operation and permitting smaller size.

Douglas J. Suda (right) joined the Power and Signal Group at Automatic Electric in 1954. He engaged in the design and development of central office power equipment, single-frequency signalling equipment, transformers, and inductors, until 1960, when he was transferred to the Electronic Applications Group to work on the design of transistorized power equipment.

Robert F. Winkler graduated from the National Radio Institute in 1934, and gained experience successively in radio service engineering, capacitor development, electronic controls and instrument engineering. Since 1959, he has been an Electronic Design Engineer, assigned to electronic development in the laboratories of Leich Electric Co. Mr. Winkler is an associate member of American Institute of Electrical Engineers.

TEST AND INSTALLER'S SET
For AT-6 Negative-Impedance Repeaters

By E. L. Roback
Automatic Electric Laboratories, I

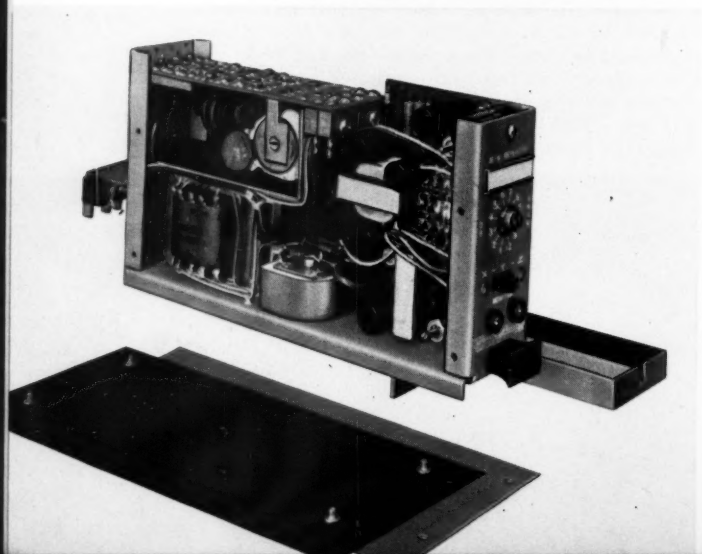
Figure 1. The Repeater Test and Installer's Set provides a jack for plugging-in the repeater under test; also, a compartment for the cord needed to connect to the exchange facilities.

Because the AT-6 Negative-Impedance Repeater* provides a combination of features that are not otherwise found in one unit, Automatic Electric Laboratories has developed a special Test and Installer's Set (Figure 1) to aid in the application of these repeaters. A combination series and shunt repeater, the AT-6 utilizes line-build-out (LBO) units to compensate for the reactive components of the line impedance, thus providing smoother gain characteristics. Screws are used as connecting elements between the components in the LBO networks (see Figure 2)—eliminating strapping and soldering irons. This new repeater uses a simple resistance-adjustable network, controlled from the front panel so it is simple to adjust in the field. The Negative-Impedance Repeater Test and Installer's Set described in this article contains all the equipment needed for installation, line-up, and test of AT-6 repeaters under most conditions. It also contains provisions for measuring standard gain performance of AT-2 and AT-3 repeaters, and for testing performance of their amplifiers.

Test Facilities

This Set may be used to measure the return loss of the circuit to be repeatered, and thus determine whether it meets transmission requirements. A built-in LBO (Line Build-Out) unit facilitates adjustment of the line building-out networks of the AT-6 repeater. Return-loss measurements of the line (or of line plus LBO) are made against a network of 900 ohms in series with 2 capacitance. An external precision network can be substituted for this network, when structural-return-loss measurements are desired.

Figure 2. The Type AT-6 repeater (shown with covers removed) is a compact, transistorized unit, with provisions for setting the LBO units by means of screws in the top panel, and for easily adjusting the resistance network from the front.



The Test Set contains provisions for measuring standard gain performance of AT-2 and AT-3 as well as of AT-6 repeaters. For AT-2 and AT-3 gain tests, the required standard gain performance networks are included in the Set. The AT-6 repeater does not require a separate standard network, since its resistive network is self-contained. The series section, shunt section, or total gain performance can be measured separately, in 500 cps increments, from 500 to 3000 cps. The Test and Installer's Set also has provision for measuring repeater insertion gain; this feature may be used when AT-6 or AT-2 repeaters are to be applied to a non-loaded cable. A "repeater overload" test is provided to aid in finding faulty transistors in AT-2, AT-3, or AT-6 repeaters.

**New Negative-Impedance Repeater Permits Accurate Impedance Matching, R. P. Dimmer, Automatic Electric Technical Journal, April, 1960.*

Incorporated in the Set is a transistorized single- and sweep-frequency oscillator. The single frequencies of the oscillator are 500 to 3000 cps in 500 cps increments. The sweep-frequency range is 2000 to 3000 cps; this frequency band is swept every one-tenth of a second. The oscillator portion of the Set contains a 600- and a 900-ohm access, for use in external applications. Likewise included in the Set is a transistorized detector, with a sensitivity range from −50 DBM to +10 DBM. The input to the detector contains a high-pass filter with a 200 cps cut-off, to limit line noise when cable return-loss measurements are made. The power input to this detector is Zener diode-regulated to insure consistent accuracy, regardless of the fluctuations of input power. The detector position of the Set also contains a 600- and a 900- ohm output access for use in external applications.

A high-impedance coil termination, accessed through the telephone jack, is provided to hold dial-up test terminations on either side of the repeater.

Double telephone jacks are provided which will also accept single-telephone-plug access in the "A" position for substituting an external oscillator, detector, or network in place of those in the Set.

Power for all tests is obtained from 48-volt exchange battery. It may be supplied to the Set either via the shelf jack provided, or via terminals on the panel.

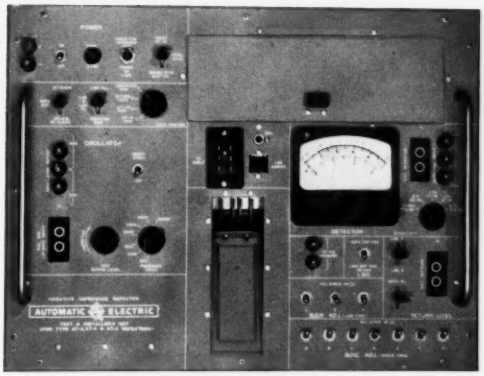


Figure 3. This is the face panel of the Repeater Test and Installer's Set.

Arrangement of Components

The oscillator and detector controls and the connecting, holding, and selecting controls on the panel are shown in Figure 3. It will be seen that the panel is divided into sections according to circuit functions, and the sections are arranged to facilitate operation of the Set with both hands. Handles at both ends of the panel make it easy to remove from the case when repairs are needed. The repeater "ramp" in the center of the test panel is provided for convenience of measurement, when repeater gain tests are to be made.

An eight-point switch jack, terminating a

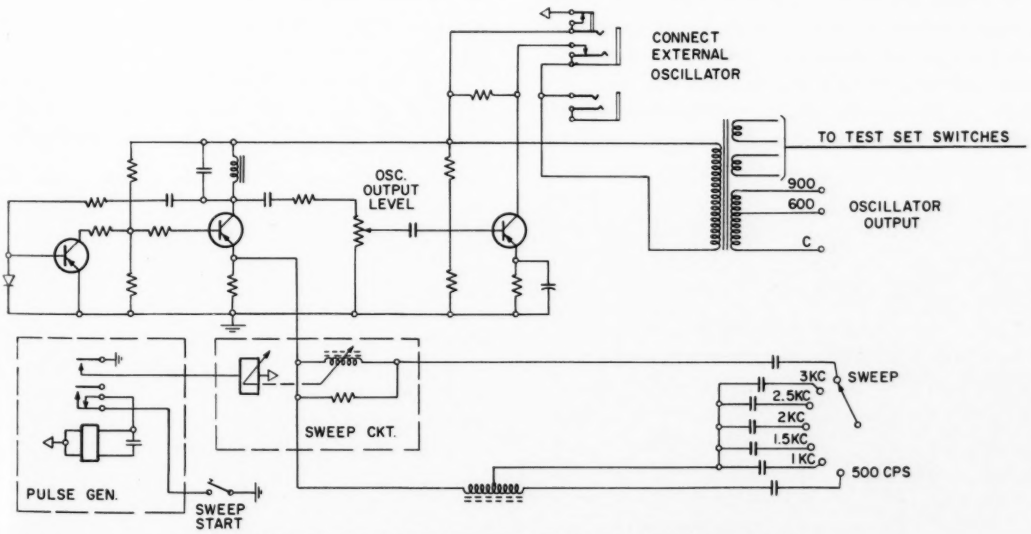


Figure 4. The transistor oscillator provides desired output frequencies by switch settings; in the "sweep" position, a relay varies inductance L-2.

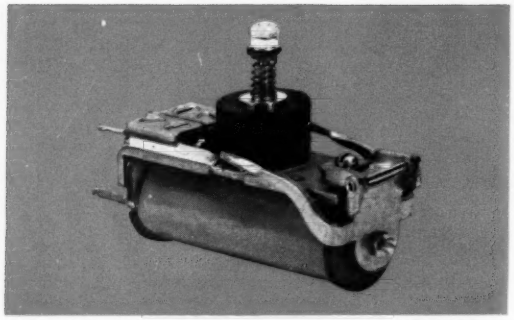


Figure 5. This novel variable-inductance relay changes the output frequency of the oscillator, thus permitting it to be used as a sweep generator.

twelve-foot cable, is included to connect the Set with the line at the exchange shelf. The carrying case, closed for carrying, is approximately (20 13/16) inches long, (15 21/32) inches wide, and (7") high. The case is made of aluminum and has a grey pebble finish. The complete Set weighs 27 lbs.

The Oscillator

Test frequencies are produced by a square-wave oscillator, coupled to a tuned Class A amplifier, as shown in Figure 4. Variation of the series resonant circuit connected to the emitter of the second transistor stage changes the output frequency of the oscillator; thus, variation of this circuit at a sweep rate of 10 times per second allows this single-frequency oscillator to be used as a sweep generator. The sweep portion of the circuit consists of a relay-type pulse generator and a relay (see Figure 5) which is modified to pulse and vary the air gap of a cup-core inductor (L-2, in Figure 4). Output frequency is well maintained; replacing the second transistor by another changed the frequency never more than 0.2%, and a 20% variation in supply voltage changes the frequency only 3.1%. In fact, this circuit oscillates readily when the supply voltage lies anywhere between 10 and 70 volts; between 30 and 70 volts the output voltage is almost proportional to the supply voltage.

A third transistor stage is utilized to increase the output power. Output may be varied by turning a knob; maximum output is +15 DBM.

The output transformer of the oscillator has two 2-ohm windings which are used for insertion-gain and return-loss measurements. The 900- and 600-ohm outputs are provided for external use of the oscillator. For such use, the test position switch, immediately above the "oscillator" portion of the panel, is placed on position 4 ("Insertion Gain"), and the individual frequencies desired are selected by operation of the frequency switch. A toggle switch is provided to turn on the sweep circuit. External equipment can be substituted via the double telephone jacks provided.

The Detector

The detector (see Figure 6) consists basically of a high-pass filter input connected to one of four 600-ohm "T" pads which are used as attenuators for the input signal. The first two stages of amplification have a feedback bias arrangement for current stabilization of both stages at any ambient temperature up to 105°F. The resistor from the emitter of the second transistor to the base of the first provides d-c feedback. From the collector of the second transistor to the emitter of the first transistor, a-c negative feedback is

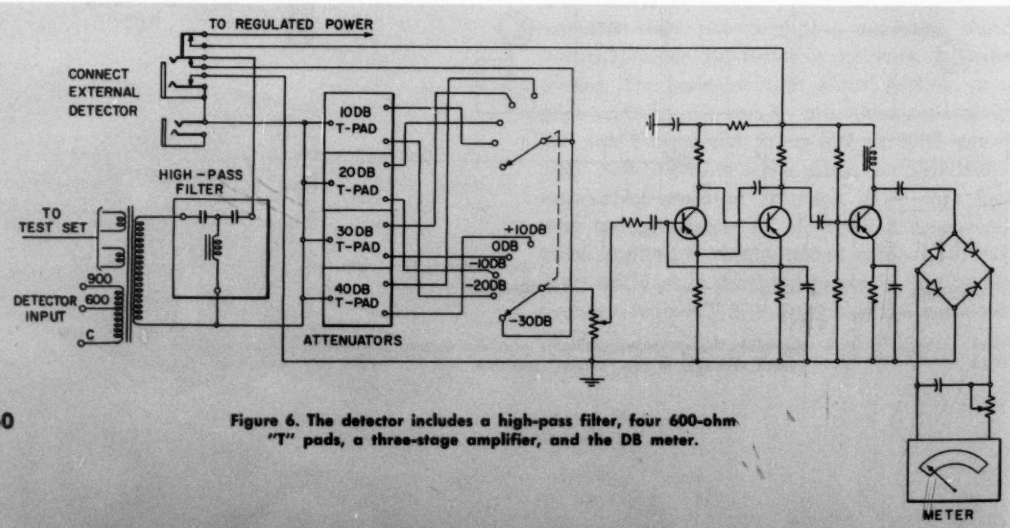


Figure 6. The detector includes a high-pass filter, four 600-ohm "T" pads, a three-stage amplifier, and the DB meter.

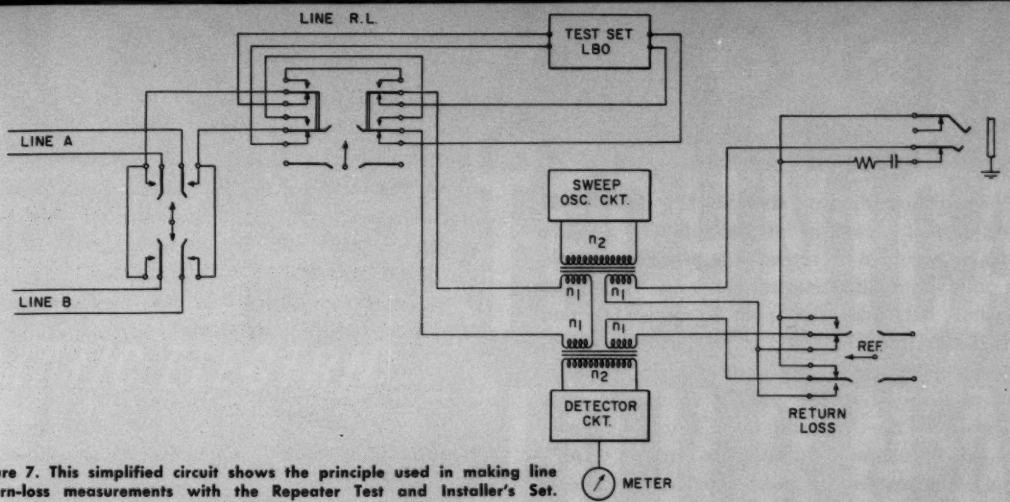


Figure 7. This simplified circuit shows the principle used in making line return-loss measurements with the Repeater Test and Installer's Set.

used. The output of the third stage is fed to a bridge rectifier, across which the meter is connected. The detector has the same options for external use as the aforementioned oscillator.

Since the power supplied to the detector is regulated, detector response is not affected by variation of input voltage. There is less than 1 DB variation in response versus frequency, over the frequency range of 500 to 3000 cps. Detector sensitivity is from −50 DBM to ±10 DBM.

Return-Loss Measurements

With the Repeater Test and Installer's Set, return-loss measurements can be made of the facility to be repeatered. The Set contains a repeater LBO unit to facilitate alignment of AT-6 repeaters on loaded facilities. The elements of this internal LBO are first connected by the toggle switches, and the switch settings are then transferred directly to repeater LBO screw settings. All return-loss measurements of the line, or line plus LBO, are made against a network of 900 ohms and 2 mf capacitance. As previously mentioned, an external network can be substituted for the above net, to allow facility structural return-loss measurements to be made.

The basic components of the return-loss measuring circuit are all passive elements which are not subject to changes in their pertinent electrical characteristics. The circuit utilizes two transformers which are connected in a bridge arrangement as shown in the simplified circuit (Figure 7). The oscillator and the detector devices are connected across the conjugate arms of the bridge. The unknown impedance and a standard network are connected across the opposite arms of the bridge circuit. Simple voltage measurements made across the detector sides of the bridge are the only determinations required for return-loss measurements; there are no critical calibrations. Thus, changes in the sensitivity of the detector, or variations in the oscillator output, will have no effect on the accuracy of the measurement.

The two transformers used are substantially identical. To secure return-loss measurements by the above method, secondary windings n_2 must be large in comparison with the primary windings n_1. A first poling of each transformer's primary winding is used as a reference or calibrate position; this arrangement provides a measure of the transmission through the transformers when the current in the unknown branch (the line to be measured) and the current in the network branch are added vectorially in the detector winding. The reverse poling of the primary winding gives a measure of the transmission through the transformers when the currents in the network and unknown branches are subtracted vectorially in the detector circuit. The difference between the two readings is, in effect, a return-loss measurement of the unknown line impedance against a known network of 900 ohms and 2 mf.

To obtain satisfactory operation of an AT-6 repeater, it is recommended that the H88 loaded facilities to which it is applied have a structural return-loss of at least 22 DB for 24-gauge exchange cable, 19 DB for 22-gauge, and 16 DB for 19-gauge. The return losses are also based on a capacitance deviation per load section (HC) of not over 2.7%, and 92 percent of the pairs meeting the above structural-return-loss requirements.

Repeater Gain Measurements

A simplified diagram showing the basic measuring circuit used in testing repeater gain, is given in Figure 8. A repeater is plugged into the Set only when gain measurements are to be made or when network alignment is made for non-loaded cable applications. In the latter case, the repeater network is adjusted and the resulting gain as applied to the facility is measured by operation of the Insertion-Gain key. Such insertion-gain measurements would be limited to AT-2 or AT-6 repeaters, on non-loaded cable or combination lines.

Since the AT-6 is a combination repeater, provisions were made to check separately the

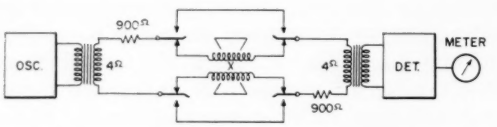


Figure 8. This simplified circuit shows the principle used in making tests for repeater gain.

operation of its series and shunt amplifier sections. When the series-section gain is checked, voltage is removed from the shunt section. When the shunt-section gain is checked, power is removed from the series section and the line side of the series-section transformer is shorted. When the overall gain is to be checked, power is supplied to both sections simultaneously. A "short test" cable, multipled at the Test Set jack, is provided to by-pass the LBO sections during this gain test. As previously stated, the gain of the AT-6 repeater can be checked at 500 cycle intervals from 500 cps to 3000 cycles.

AT-2 or AT-3 repeaters may also be gain-checked with this Set. The repeater to be measured is plugged into the Set, and the network terminals of the unit (#24 and #36 of the repeater network) must then be connected to the network terminals on the panel. When the associated repeater-gain key is operated, the respective standard network is switched to these panel terminals. No external pads or equipment are required for these tests. Circuit operation is similar to that shown in Figure 6.

A "transistor overload" check is included, to aid in determining the performance of amplifiers in the AT-2, AT-3, and AT-6 repeaters. Essentially, the overload test checks the amplification of the repeater with full voltage and with half voltage applied. A good repeater should deliver the same gain under both conditions. A push-button is provided for this test, in the "power" section of the Test Set panel.

Conclusion

The Repeater Test and Installer's Set contains features which permit evaluation of cable plant as well as of repeater performance. All apparatus necessary for these tests is self-contained; no auxiliary equipment is necessary. The built-in LBO unit permits rapid repeater LBO settings when there is no AT-6 repeater on hand. The oscillator and detector portions of the set can be accessed for external use, and thus can be employed for various other purposes, in the telephone plant.

E. L. Roback became one of Automatic Electric's "Co-op" students at Northwestern University in 1954, and for the next three years divided his time between A.E. and N.U. Following graduation in 1957, with a B.S.E.E., he joined the Electronic Application section of Laboratories' Production Design department. Before becoming involved in the development of negative-impedance repeaters, and associated test and installer's sets, Mr. Roback was directly associated with the development of the first "compatible" dial mobile telephone system and the "waystation dialing" system for railroads.